MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXX. FEBRUARY 11, 1910. NO. 4

ANNUAL GENERAL MEETING.

SIR DAVID GILL, K.C.B., F.R.S., PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1909 was read, and is given on p. 382.

The Annual Report of the Council was partly read; see pp. 279 to 394.

The Address was delivered by the President, after which the Gold Medal was handed to Professor Friedrich Küstner, to whom it had been awarded "For his Catalogue of Stars, his pioneer determination of the Aberration Constant from motions in the line of sight, and his detection of the Variation of Latitude" (see pp. 395 to 413).

The following motions, which had been recommended by the Council, and of which due notice had been given to the Fellows, were put to the Meeting and carried:—

That Bye-Law 73 be amended to read as follows:—

73. Whenever one person or more shall have been proposed, the Council shall, at their regular meeting in December, either decide that no Medal shall be given, or select one of the persons so proposed, to be submitted to the Council in January following.

That in Bye-Law 22 the words "or June" be substituted for "June or July," and that the word "October" be inserted before "November."

Bye-Law 22 therefore now stands:—

22. . . . two guineas as the first year's contribution if such election has taken place in the month of February, March, April,

May, or June; but only one guinea as the first year's contribution if such election has taken place in the month of October, November, December, or January. . . .

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 414.

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

John Knight Fotheringham, M.A., D.Litt., Lecturer in Ancient History at King's College, London;
Edward Rupert Hicks, 67 Holland Road, Kensington, W.;
Alfred Harrison Joy, M.A., Director of the Observatory, Syrian Protestant College, Beirût, Syria;
Rev. D. Kennedy, Meeanee, Napier, New Zealand;
William J. MacDonnell, Falmouth Chambers 4, Pitt Street 117, Sydney, New South Wales, Australia; and
Stanley Maxwell, M.A., LL.B., Manor House School, Clapham Common, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Percy Christopher Charles Billups, M.R.C.S., L.R.C.P., Barry Island, Glamorgan (proposed by J. N. Jutsum);
Selig Brodetsky, B.A., Trinity College, Cambridge (proposed by F. J. M. Stratton);
Capt. Charles Edward Monro, R.N., Assistant Hydrographer, Admiralty (proposed by Sir William Christie); and
John Storey, Royal Observatory, Edinburgh (proposed by Sir William Christie).

Report of the Council to the Ninetieth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society:—

	Patron	Honorary Members	Fellows		Associates	Total
			Compounders	Annual Subscribers		
1908 December 31	1	2	261	411	47	722
Since elected	...	...	+4	+32	+2	...
Deceased	...	...	−5	−8	−2	...
Resigned	...	...	...	−6	...	...
Since compounded	...	...	+1	−1	...	...
Removed	...	...	...	−7	...	...
1909 December 31	1	2	261	421	47	732

Major Hills' Account as Treasurer of the Royal

RECEIVED.

	£ s. d.	£ s. d.
Balances, 1908 December 31 :—		
At Bankers', as per Pass-book	453 16 11	
Cheques not credited till 1909	4 4 3	
In hand of Assistant Secretary on Account of Turnor and Horrox Fund	1 0 11	
In hand of Assistant Secretary on Petty Cash Account	1 16 3	
		460 18 4
Dividends :—		
£1,250 Metropolitan 3-per-cent. Stock ...	35 7 11	
£2,000 Swansea Corporation 3½-per-cent. Stock	65 12 5	
£3,500 East Indian Railway 3-per-cent. Debenture Stock	99 1 10	
£3,500 London and North-Western Railway 3-per-cent. Debenture Stock	99 10 7	
£4,000 Midland Railway 2½-per-cent. Debenture Stock	94 15 10	
£500 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock ...	14 4 4	
£2,000 Gas Light and Coke Co. 3-per-cent. Debenture Stock	54 17 7	
£1,650 Commercial Gas Co. 3-per-cent. Debenture Stock	46 14 4	
		510 4 10
Interest on money on deposit at Bankers'		3 13 6
Received on account of Subscriptions :—		
Arrears	200 11 0	
Annual Contributions for 1909	623 14 0	
,, ,, for 1910 in advance	8 8 0	
Admission Fees	67 4 0	
First Contributions	46 4 0	
		946 1 0
Composition Fees...		131 5 0
Sales of Publications, &c. :—		
At Williams & Norgate's, 1908	26 3 3	
At Society's Rooms, 1909	117 12 4	
Sale of Photographs, 1909	53 4 6	
		197 0 1
Income Tax refunded by Commissioners of Inland Revenue		26 13 4
Cheque outstanding		7 10 0
Due to Assistant Secretary on account of Turnor and Horrox Fund		1 8
		£2,283 7 9

Examined and found correct, January 12, 1910.

DAVID SMART.
W. SHACKLETON.
W. E. ROLSTON.

Astronomical Society from January 1 to December 31, 1909.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
,, ,, Editing Society's Publications	50	0	0			
Clerk's Salary	78	2	6			
				378	2	6
House Duty	2	12	6			
Fire and Servants' Insurance	9	12	6			
				12	5	0
Printing, etc.:—						
Monthly Notices	421	11	0			
Memoirs, Vol. 59, Parts 2 and 3	141	0	4			
Photo-Engraving and Lithography	42	1	9			
Miscellaneous Printing	55	7	0			
				660	0	1
Reproduction of Photographs for Sale				59	18	6
Cataloguing Astronomical Literature for the International Catalogue of Scientific Literature ...				30	0	0
Turnor and Horrox Fund, purchase of books for Library	21	2	7			
Binding for Library	2	4	9			
				23	7	4
Expenses of Meetings	17	6	9			
Lantern expenses	13	6	2			
Time Signal: rental of wire	5	0	0			
Conversazione expenses	12	8	1			
				48	1	0
Postage and Telegrams	124	9	0			
Carriage of Parcels	5	16	10			
Stationery and Office expenses	14	13	7			
				144	19	5
House expenses: Allowance and sundry expenses	59	4	9			
Coal and Gas	35	5	10			
Electric Lighting	23	5	5			
Fittings and Repairs	28	8	5			
Sundries	4	14	4			
				150	18	9
Jackson Gwilt Gift to Mr. P. J. Melotte				25	0	0
Purchase of £140 Gaslight & Coke Co. 3-per-cent. Debenture Stock @ 85½, including Commission	121	2	0			
Purchase of £100 East Indian Railway 3-per-cent. Debenture Stock @ 81½, including Commission	82	10	6			
Purchase of £35 7*s.* 5*d.* Swansea Corporation 3½-per-cent. Stock @ 100⅝, including Commission	35	14	3			
				239	6	9
Cheque-book and deductions on cheques					10	8
Balances, 1909 December 31:—						
At Bankers', as per Pass-book	491	0	5			
Cheque not credited till 1910	14	12	0			
In hand of Assistant Secretary on Petty Cash Account	5	5	4			
				510	17	9
				£2,283	7	9

Report of the Auditors.

We have examined the Treasurer's account of receipts and expenditure for the year 1909, and have found and certified the same to be correct. The cash in hand on December 31, 1909, including the balance at the bankers', etc., amounted to £510 17*s.* 9*d.*

The funded property of the Society has been increased by the purchase of £140 Gaslight and Coke Company 3-per-cent. Debenture Stock, £100 East Indian Railway 3-per-cent. Debenture Stock, and £35 7*s.* 5*d.* Swansea Corporation 3-per-cent. Stock.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

DAVID SMART.
W. SHACKLETON.
W. E. ROLSTON.

11*th. February* 1910.

Gifts to the General Funds of the Society.

In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq, for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols. This was sold in 1899, and stands now in £1,881 14*s.* London and North-Western Railway 3-per-cent. Debenture Stock.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty. This now stands in £1,871 1*s.* 6*d.* Swansea Corporation $3\frac{1}{2}$-per-cent. Stock.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty. This now stands in £93 11*s.* 1*d.* Swansea Corporation $3\frac{1}{2}$-per-cent. Stock.

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

The Turnor Fund and the Horrox Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrox: to this the Society added the sum of £55 15*s.*, and the whole now stands in £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1910 January 1.

	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
Balances, 1909 December 31 :—									
At Bankers', as per Pass-book ...	491	0	5						
Cheque not credited till 1910 ...	14	12	0						
In hand of Assistant Secretary on Petty Cash Account	5	5	4						
				510	17	9			
Less due to Assistant Secretary on account of Turnor and Horrox Fund		1	8						
,, Cheque outstanding	7	10	0						
,, Cost of £350 Commercial Gas 3-per-cent. Debenture Stock, not debited till January 1910	291	17	6						
				299	9	2			
							211	8	7
Due on account of Subscriptions :—									
7 Contributions of 3 years' standing	44	2	0						
35 ,, 2 ,, ,,	147	0	0						
67 ,, 1 ,, ,,	140	14	0						
Other sums	10	10	0						
5 Admission Fees and First Contributions	15	15	0						
				358	1	0			
Less Subscriptions paid in advance				8	8	0			
							349	13	0
Due for Publications				...	...		5	0	0
Due from Williams & Norgate for Publications sold during 1909							20	18	6

£1,250 Metropolitan 3-per-cent. Stock.

£2,000 Swansea Corporation 3½-per-cent. Stock (including the McClean and Farrar Bequests).

£3,500 East Indian Railway 3-per-cent. Debenture Stock (including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (*née* Gwilt) Fund).

£500 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£3,500 London and North-Western Railway 3-per-cent. Debenture Stock (including the Carrington Bequest).

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock.

£2,000 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Two Gold Medals.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
,, 2. The *Owen* portable circles, by Jones.
,, 3. The *Beaufoy* circle (without stand).
,, 4. The *Beaufoy* transit instrument (without stand).
,, 5. The *Herschel* 7-foot reflector.
,, 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
,, 7. The *Smeaton* equatorial.
,, 8. The *Cavendish* apparatus.
,, 9. 7-foot Gregorian telescope.
,, 10. Variation transit instrument.
,, 11. Universal quadrat, by Abraham Sharp.
,, 12. The *Fuller* theodolite.
,, 13. The 5-foot tubular standard scale.
,, 14. The *Beaufoy* clock, No. 1.
,, 15. The *Beaufoy* clock, No. 2.
,, 16. The *Wollaston* 3½-inch telescope (without stand).
,, 17. The *Lee* circle.
,, 18. The *Sharpe* reflecting circle.
,, 19. The *Brisbane* circle.
,, 20. The *Baker* universal equatorial; aperture 1⅜ inches.
,, 21. The *Reade* transit; aperture 2½ inches.

No. 22. The *Matthew* 4-inch refractor, by Cooke, with equatorial stand and clock movement.

„ 23. The *Matthew* transit instrument; aperture $2\frac{3}{4}$ inches, with stand.

„ 24. The *South* 7-foot transit instrument, by Edward Troughton, aperture 4 inches (without stand).

„ 25. Sextant, by Bird (formerly belonging to Captain Cook).

„ 26. Globe showing the precession of the equinoxes.

The *Sheepshanks* collection:—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.

„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye end, reading to single minutes; horizontal circle, in brass, 9 inches diameter, to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter

and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

No. 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) 11-inch reflecting circle, by Jecker, of Paris, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon and stand.

„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches; tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; two beam compasses.

„ 62. (36) A pantograph.

„ 63. (37) A noddy.

„ 64. (38) Galilean telescope, with $1\frac{5}{8}$-inch object-glass of rock crystal.

„ 65. (39) Five levels.

„ 69. (43) Telescope, with $4\frac{5}{8}$-inch object-glass of rock crystal.

No. 71. Portable altazimuth tripod.
,, 72. Four polarimeters.
,, 74. Registering spectroscope, with one large prism.
,, 76. Two five-prism direct-vision spectroscopes.
,, 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
,, 79. Spectroscope.
,, 80. Box containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
,, 81. Back-staff, or Davis' quadrant.
,, 82. Nocturnal or star dial.
,, 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
,, 85. Double-image micrometer, by Troughton and Simms.
,, 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
,, 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope, with wooden tripod stand.
,, 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
,, 89. Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box divided into compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
,, 90. Arabic $5\frac{3}{4}$-inch celestial globe of bronze.
,, 91. Astronomical time watch-case, by Professor Chevallier.
,, 92. 2-foot protractor, with two movable arms, and vernier.
,, 93. Beam compass, in box.
,, 94. 2-foot navigation scale.
,, 95. Stand for the 5-foot tubular standard scale.
,, 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
,, 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
,, 99. 12-inch transit instrument, aperture $1\frac{1}{4}$ inches, by Fayrer and Son, with level and portable stand.
,, 100. 9-inch transit instrument, aperture $1\frac{1}{4}$ inches, with level and iron stand.
,, 101. Improved sun-dial, by G. Adams, London.
,, 102. Sun-dial, by Troughton.
,, 103. Sun-dial, by Casella.
,, 104. Sun-dial.
,, 105. Box sextant, by Troughton and Simms.
,, 106. Prismatic compass, by Schmalcalder, London.
,, 107. Compass, by C. Earle, Melbourne.
,, 108. Prismatic compass, by Negretti and Zambra.
,, 109. Dipleidoscope, by E. Dent.

No. 110. Abney level, by Elliott.
,, 111. Pocket spectroscope, by Browning.
,, 112. 4-inch ring dial.
,, 113. Double sextant, by Jones.
,, 114. Two models, illustrating the effects of circular motions.
,, 115. Cometarium.
,, 117. Two old sun-dials.
,, 118. 10½-inch sixteenth-century celestial globe, on bronze tripod stand.
,, 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
,, 120. 6-prism spectroscope, by Browning.
,, 121. Spitta's improved maximum and minimum thermometer.
,, 122. 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured Sir J. Herschel.
,, 123. 6-inch refracting telescope, by Grubb, with 3 eyepieces (no stand).
,, 124. Position micrometer, by Cooke.
,, 125. 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal (no stand).
,, 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
,, 127. Two globes representing the visible surface of the Moon, by John Russell, R.A., 1797 (one mounted to show libration, etc.).
,, 129. Slater's improved armillary sphere.
,, 130. 10-inch brass pillar sextant, with counterpoise stand, by Troughton.
,, 131. Double box sextant, by Cary.
,, 132. The *Waters* equatorially mounted camera, with 2½-inch portrait lens and telephotographic enlarging lens, by Dallmeyer; iron pillar.
,, 133. 3¼-inch refractor by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer.
,, 134. Old transit instrument, 2-inch aperture and 3 feet focal length (without stand), formerly belonging to Dr. Longfield, of Cork.
,, 135. Two globes of Mars, by L. Niesten and E. M. Antoniadi.
,, 136. Universal instrument, with stand, by W. and S. Jones; the telescope 1½-inch aperture and 15 inches focal length.
,, 137. Polar siderostat, by Hilger, with 4⅛-inch mirrors.
,, 138. Transit instrument, aperture 2¾ inches, with collimator and stand.
,, 139. Transit instrument, aperture 1 1/16-inch, with portable stand.
,, 140. 3¾-inch object-glass and tube.
,, 141. The *Cross* 9-inch reflector and equatorial stand.
,, 142. Position micrometer, by Dallmeyer, formerly belonging to Captain Noble.
,, 143. 6-inch Ring dial, with stand.

No. 144. $2\frac{3}{4}$-inch Ring dial.
,, 145. 12-inch level, reading to 1″.
,, 146. Microscope, with large stage for examining photographic plates.

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
Abney doublet lens used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
Cœlostat, with 16-inch plane mirror.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject and Date.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*, 1888 December 8	Isaac Roberts
5	Nebula M 74 *Piscium* (N.G.C. 628), 1893 December 9	Isaac Roberts
6	Great Nebula in *Orion*, 1888 December 24	Isaac Roberts
7	Milky Way near M 11, 1892 June 29	E. E. Barnard
8	Milky Way near Cluster in *Perseus*, 1893 November 3	E. E. Barnard
9	Comet 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η *Argus*, 1892 March 3	David Gill
12	Portion of Moon (Hyginus-Albategnius), 1894 March 14	Loewy and Puiseux
13	Comet 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.), 1894 February 13	Loewy and Puiseux
20	Nebula in *Andromeda*, 1888 December 29	Isaac Roberts

R.A.S. Ref. No.	Subject and Date.	Photographed by
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis* (N.G.C. 6205), 1894 August 5	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age 7d. 3h.), 1890 September 21	Lick Observatory
26	The Moon (Age 12d. 6½h.), 1891 August 16	Lick Observatory
27	The Moon (Age 16d. 18h.), 1890 August 31	Lick Observatory
28	The Moon (Age 23d. 8h.), 1891 July 28	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of Maginus), 1894 February 13	Loewy and Puiseux
32	The Moon (Age 14d. 1h.), 1890 October 27	Lick Observatory
33	Portion of Moon (Ptolemæus, &c.), 1895 October 9	Lick Observatory
34	Portion of Moon (Mare Serenitatis), 1895 October 7	Lick Observatory
35	Portion of Moon (Clavius, Licetus), 1895 October 8	Lick Observatory
36	Portion of Moon (Regiomontanus), 1895 October 8	Lick Observatory
37	Portion of Moon (Tycho, Thebit), 1895 October 9	Lick Observatory
38	Portion of Moon (Theophilus, &c.), 1895 October 7	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ* (N.G.C. 6779), 1896 May 9	
42	Nebulæ M 81, 82 *Ursæ Majoris* (N.G.C. 3031, 3034), 1896 May 10	
43	Cluster M 56 *Lyræ* (N.G.C. 6779) (enlarged), 1896 May 9	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 Sept. 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster

R.A.S. Ref. No.	Subject and Date.	Photographed by
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*, 1897 January 23	W. E. Wilson
57	Dumb-bell Nebula, N.G.C. 6853, 1894 August 6	W. E. Wilson
58	Spiral Nebula, N.G.C. 5194–5, 1897 March 6	W. E. Wilson
59	Ditto (enlarged), N.G.C. 5194–5, 1897 March 6	W. E. Wilson
60	Annular Nebula, *Lyra* (N.G.C. 6720), 1894 September 9	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 Nov. 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*, 1898 September 23	Roy. Obs., Greenwich
67	Spectrum of Sun's Limb, 1898 January 22	E. H. Hills
68	Annular Nebula, *Lyra* (N.G.C. 6720), 1899 July 14	Lick Observatory
69	Dumb-bell Nebula, N.G.C. 6853, 1899 July 31	Lick Observatory
70	Spiral Nebula, N.G.C. 5194–5, 1899 May 10	Lick Observatory
71	Spiral Nebula, *Ursa Major* (N.G.C. 5457), 1899 June 8	Lick Observatory
72	Trifid Nebula, *Sagittarius* (N.G.C. 6514), 1899 July 6	Lick Observatory
73	Great Nebula in *Orion*, 1898 December 11	Lick Observatory
74	Cluster M 13 *Herculis* (N.G.C. 6205), 1899 July 13	Lick Observatory
75	Solar Surface with Faculæ, 1893 August 7	G. E. Hale
76	Faculæ and Prominences, 1892 June 25	G. E. Hale
77	Total Solar Eclipse, 1898 January 22 ($\frac{2}{3}$ sec.)	W. H. M. Christie
78	Nebula H V.14 *Cygni* (N.G.C. 6992), 1899 October 7	W. E. Wilson
79	Portion of Moon (Theophilus, &c.), 1900 October 12	Yerkes Observatory
80	Total Solar Eclipse, 1900 May 28 (30 sec.)	E. E. Barnard
81	Comet 1901 I., 1901 May 4	Roy. Obs., Cape of G. H.
82	Comet 1901 I., 1901 May 6	Roy. Obs., Cape of G. H.

R.A.S. Ref. No.	Subject and Date.	Photographed by
83	Comet 1901 I., 1901 May 9	Perth Obs., W. Australia
84	Solar Surface with Faculæ, 1895 August 18	H. Deslandres
85	Solar Prominences, 1894 April 11	H. Deslandres
86	Nebula about Nova *Persei*, 1901 Septem. 20	G. W. Ritchey
87	Nebula about Nova *Persei*, 1901 Novem. 13	G. W. Ritchey
88	Total Solar Eclipse, 1901 May 18 (10 sec.)	F. W. Dyson
89	Total Solar Eclipse, 1901 May 18 (40 sec.)	F. W. Dyson
90	Comet 1902 III. (Perrine), 1902 Septem. 29	Roy. Obs., Greenwich
91	Portion of Moon (Mare Serenitatis), 1901 August 3	Yerkes Observatory
92	Portion of Moon (Mare Nubium, &c.), 1901 November 21	Yerkes Observatory
93	Portion of Moon (Tycho, Theophilus), 1900 October 12	Yerkes Observatory
94	Portion of Moon (Bullialdus, Copernicus), 1901 November 20	Yerkes Observatory
95	Portion of Moon (Copernicus, enlarged), 1901 November 20	Yerkes Observatory
96	Great Nebula in *Orion*, 1901 October 19	Yerkes Observatory
97	Ditto (Central portion), 1901 January 20	Yerkes Observatory
98	Nebula in *Andromeda*, 1901 September 18	Yerkes Observatory
99	Nebula in *Cygnus* (N.G.C. 6960), 1902 August 1	Yerkes Observatory
100	Nebula H V. *Cygni* (N.G.C. 6992), 1901 October 5	Yerkes Observatory
101	Cluster M 13 *Herculis* (N.G.C. 6205), 1901 April 25	Yerkes Observatory
102	Cluster M 15 *Pegasi* (N.G.C. 7078), 1900 October 3	Yerkes Observatory
103	Solar Surface with Faculæ, 1903 April 27	Yerkes Observatory
104	The Moon, 1900 April 5	P. Puiseux
105	The Moon, 1902 November 13	P. Puiseux
106	The Moon, 1903 February 6	P. Puiseux
107	The Moon, 1903 September 12	P. Puiseux
108	Nebulosity about 15 *Monocerotis*, 1894 February 1	E. E. Barnard
109	Milky Way about β *Cygni*, 1893 October 12	E. E. Barnard
110	Nebulosity near α *Cygni*, 1893 October 5	E. E. Barnard
111	Milky Way near χ *Cygni*, 1892 October 20	E. E. Barnard
112	Star Cloud in *Sagittarius*, 1892 June 20	E. E. Barnard

R.A.S. Ref. No.	Subject and Date.	Photographed by
113	Milky Way in *Cepheus*, 1893 October 13	E. E. Barnard
114	Milky Way about M 8, 1894 July 5	E. E. Barnard
115	Milky Way about *θ Ophiuchi*, 1894 July 6	E. E. Barnard
116	Milky Way near N.G.C. 6475, 1894 July 26	E. E. Barnard
117	Great Nebula near *ρ Ophiuchi*, 1895 June 21–2	E. E. Barnard
118	Milky Way about 58 *Ophiuchi*, 1895 June 26	E. E. Barnard
119	Milky Way near *Omega* nebula, 1895 July 25	E. E. Barnard
120	Star Cloud in *Sagittarius*, 1895 August 13	E. E. Barnard
121	Nebula about *ν Scorpii*, 1895 May 23	E. E. Barnard
122	Sun, 1905 January 30	Roy. Obs., Greenwich
123	Sun-spot, 1905 January 30	Roy. Obs., Greenwich
124	Sun, 1905 January 31	Roy. Obs., Greenwich
125	Sun-spot, 1905 January 31	Roy. Obs., Greenwich
126	Sun, 1905 February 2	Roy. Obs., Greenwich
127	Sun-spot, 1905 February 2	Roy. Obs., Greenwich
128	Sun, 1905 February 3	Roy. Obs., Greenwich
129	Sun-spot, 1905 February 3	Roy. Obs., Greenwich
130	Sun, 1905 February 5	Roy. Obs., Greenwich
131	Sun-spot, 1905 February 5	Roy. Obs., Greenwich
132	Sun, 1905 February 8	Roy. Obs., Greenwich
133	Sun-spot, 1905 February 8	Roy. Obs., Greenwich
134	Nebula near *ψ Eridani*, 1905 January 8	Max Wolf
135	Nebula M 33 *Trianguli* (N.G.C. 598), 1895 November 14	Isaac Roberts
136	Nebula in *Perseus* (N.G.C. 1499), 1897 December 18	Isaac Roberts
137	Nebula in *Monoceros* (N.G.C. 2237–9), 1899 March 5	Isaac Roberts
138	Nebula H V. 24 *Comæ* (N.G.C. 4565), 1896 May 11	Isaac Roberts
139	Nebulæ H V. 42, &c., *Comæ* (N.G.C. 4631), 1894 March 29	Isaac Roberts
140	Nebula H V. 37 *Cygni* (N.G.C. 7000?), 1896 October 10	Isaac Roberts
141	Nebula Index Cat. 405 *Persei*, 1902 January 14	Isaac Roberts
142	Clusters in *Perseus* (N.G.C. 869, 884), 1895 October 12	Isaac Roberts
143	Cluster H VI. 30 *Cassiopeiæ* (N.G.C. 7789), 1898 December 17	Isaac Roberts
144	Total Solar Eclipse, 1905 August 30 (5 sec.)	W. H. M. Christie

R.A.S. Ref. No.	Subject and Date.	Photographed by
145	Total Solar Eclipse, 1905 August 30 (20 sec.)	W. H. M. Christie
146	Total Solar Eclipse, 1905 August 30 (7 sec.)	W. H. M. Christie
147	Total Solar Eclipse, 1905 August 30 (20 sec.)	W. H. M. Christie
148	Total Solar Eclipse, 1905 August 30 (Portion)	W. H. M. Christie
149	Region of Nebula ρ *Ophiuchi*, 1905 April 5	E. E. Barnard
150	Nebula ρ *Ophiuchi* (enlarged), 1905 April 5	E. E. Barnard
151	Region of θ *Ophiuchi*, 1905 June 5	E. E. Barnard
152	Great Rift near θ *Ophiuchi*, 1905 June 28	E. E. Barnard
153	Great Star Cloud in *Sagittarius*, 1905 June 29	E. E. Barnard
154	Small Star Cloud in *Sagittarius*, 1905 July 31	E. E. Barnard
155	Region of Cluster M 11, 1905 July 30	E. E. Barnard
156	Sun-spots, 1906 July 6	Roy. Obs., Greenwich
157	Sun-spot, 1906 July 31	Roy. Obs., Greenwich
158	Sun-spot, 1906 August 3	Roy. Obs., Greenwich
159	Eclipse, 1905 August 30 (large prominence)	De la Baume Pluvinel
160	Comet *c* 1908, Sept. 7d. 14h. 56m.	Roy. Obs., Greenwich
161	Comet *c* 1908, Sept. 14d. 8h. 22m.	Roy. Obs., Greenwich
162	Comet *c* 1908, Sept. 29d. 13h. 12m.	Roy. Obs., Greenwich
163	Comet *c* 1908, Sept. 29d. 14h. 13m.	Roy. Obs., Greenwich
164	Comet *c* 1908, Sept. 29d. 15h. 19m.	Roy. Obs., Greenwich
165	Comet *c* 1908, Sept. 29d. 16h. 15m.	Roy. Obs., Greenwich
166	Comet *c* 1908, Oct. 3d. 9h. 4m.	Roy. Obs., Greenwich
167	Comet *c* 1908, Oct. 3d. 13h. 13m.	Roy. Obs., Greenwich
168	Comet *c* 1908, Oct. 27d. 10h. 2m.	Roy. Obs., Greenwich
169	Comet *c* 1908, Oct. 29d. 7h. 3m.	Roy. Obs., Greenwich
170	Comet *c* 1908, Oct. 30d. 7h. 47m.	Roy. Obs., Greenwich
171	Comet *c* 1908, Nov. 3d. 6h. 43m.	Roy. Obs., Greenwich
172	Comet *c* 1908, Oct. 1d. 8h. 55m.	Roy. Obs., Greenwich
173	Comet *c* 1908, Oct. 30d. 6h. 56m.	Roy. Obs., Greenwich
174	Comet *c* 1908, Sept. 30d. 20h. 57m.	E. E. Barnard
175	Comet *c* 1908, Oct. 1d. 14h. 45m.	E. E. Barnard
176	Comet *c* 1908, Oct. 1d. 19h. 15m	E. E. Barnard
177	Comet *c* 1908, Oct. 15d. 12h. 57m.	E. E. Barnard
178	Sun-spot Vortices, 1908 Oct. 7	G. E. Hale
179	Total Solar Eclipse, 1908 Jan. 3 (16 sec.)	W. W. Campbell
180	Comet *c* 1908, Oct. 16d. 15h. 32m.	E. E. Barnard
181	Comet *c* 1908, Nov. 16d. 13h. 10m.	E. E. Barnard
182	Comet *c* 1908, Nov. 19d. 6h. 4m.	Roy. Obs., Greenwich
183	Comet *c* 1908, Nov. 22d. 5h. 55m.	Roy. Obs., Greenwich
184	Comet *c* 1908, Nov. 25d. 5h. 55m.	Roy. Obs., Greenwich

R.A.S. Ref. No.	Subject and Date.	Photographed by
185	Stellar spectra, types I., II., III.	Stonyhurst Observatory
186	Progressive spectra, types I. and II.	Stonyhurst Observatory
187	Spectrum of γ *Cassiopeiæ*	Stonyhurst Observatory
188	Spectra of o *Ceti*, 1897 and 1906	Stonyhurst Observatory
189	Spectra of o *Ceti* (1897) and α *Herculis* (1898)	Stonyhurst Observatory
190	Spectra of β *Aurigæ*, 1906	Stonyhurst Observatory
191	Spectra of *Nova Persei* (1901 Feb. 28) and *Castor* (Feb. 19)	Stonyhurst Observatory
192	Alternating spectra, *Nova Persei* (1901 March 21–28)	Stonyhurst Observatory
193	Titanium oxide flutings in o *Ceti*	A. Fowler
194	Stereogram, Comet c 1908 (Oct. 15)	E. E. Barnard
195	Stereogram, Comet c 1908 (Nov. 16)	E. E. Barnard
196	Stereogram, Comet c 1908 (Nov. 18)	E. E. Barnard
197	Mars, 1909 October 5	G. E. Hale
198	Mars, 1909 November 3	G. E. Hale
199	Spectra of Moon and Major Planets	Lowell Observatory
200	4-prism Spectrograph of Newall Telescope	Cambridge Observatory
201	Spectra of high and low Sun	G. Higgs
202	Spectrum of α Persei, 1902 September 19	H. F. Newall
203	Spectra of Earliest Stars	W. Huggins
204	Spectra of Early Stars	W. Huggins
205	Spectra of Early Solar Stars	W. Huggins
206	Spectra of Pre-solar Stars	W. Huggins
207	Spectra of Solar and Post-solar Stars	W. Huggins
208	Spectra of Double Stars	W. Huggins

Nos. 44–55, Nos. 64, 65, and No. 147 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs (excepting Nos. 194–196) are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches; also unmounted, and as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, $6\frac{1}{4}$ inches square.

Price of prints, mounted 1*s.* 6*d.* each, unmounted 1*s.* each; lantern slides, 1*s.* each; packing and postage extra.

Transparencies, $6\frac{1}{4}$ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Nos. 194–196 are for the stereoscope, and are not supplied as lantern slides. Transparencies, 2*s.* each; mounted aristotype prints, 1*s.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be

stated whether platinotypes or aristotypes are required, and whether mounted or unmounted.

The Gold Medal.

The Council have awarded the Gold Medal of the Society to Professor Friedrich Küstner, of the Royal Observatory, Bonn, for his Catalogue of Stars, his pioneer determination of the Aberration Constant from motions in the line of sight, and his detection of the Variation of Latitude. The President, in his Address to the Society, sets forth the grounds upon which the award has been founded.

Publications of the Society.

During the past year vol. lxix. of the *Monthly Notices* has been issued.

The following parts of *Memoirs* have also been published :—

Vol. lix. part iii. R. A. Sampson. On the old observations of Jupiter's Satellites.

„ part iv. F. J. M. Stratton. The Constants of the Moon's physical libration.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—Captain Edward Barnes.
John Cassells.
Lieut.-Col. W. St. L. Chase.
Samuel Chatwood.
Bryan Cookson.
Henry Zouch Darrah.
Thomas Gordon.
Eugen von Gothard.
Frederic Newton.
John Peter George Smith.
William Ford Stanley.
Captain Henry Toynbee.
Jesse Young.
Associates:—George Washington Hough.
Simon Newcomb.

John Cassells was a well-known amateur astronomer in the West of Scotland, a prominent citizen of Glasgow, and an officer of long service in the 3rd Lanark Volunteers, of which regiment he became a Major, and received the Volunteer decoration. He went to Vadsö in 1896 August with the British Astronomical Association to observe the total eclipse, and at the time of his death he was President of the West of Scotland branch of the Association.

He contributed no papers to the Society. He died on 1909 July 16.

He was elected a Fellow on 1903 January 9.

Bryan Cookson was the eldest son of the late Norman C. Cookson, of Wylam-on-Tyne, and a grandson of Robert Stirling Newall, F.R.S., of Gateshead; he was born on 1874 April 23. He was educated at Harrow and at Magdalen College, Oxford, and early showed the genius for astronomy which he had, perhaps, inherited from his grandfather. On leaving Oxford he travelled for two years, and then decided to devote his life to astronomy. In 1898 he went up to Trinity College, Cambridge, as a research student, and began at the Cambridge Observatory the excellent work which has been cut short by his early death. His first published work was, "On the accuracy of Eye-observations of Meteors, and the determination of their radiant point" (*M.N.*, 1901 January)—the thesis by which he obtained the degree of Bachelor of Arts at Cambridge. Meanwhile he had designed and

obtained a new form of floating photographic zenith telescope, with the purpose of investigating the constant of aberration and the variation of latitude. An account of this instrument is given in *M.N.*, 1901 March. After some preliminary work with it, he decided to suspend the investigation, and to accept the invitation of Sir David Gill to spend some time at the Royal Observatory at the Cape. There he carried out with the heliometer an elaborate investigation on the orbits of the four Galilean Satellites of Jupiter, on which he based a new determination of the elements of the satellites and of the mass of Jupiter. A further investigation, based on photographs, provides the means of comparing the merits of the heliometric and photographic methods. The two memoirs, his principal published work, are in the *Annals* of the Cape Observatory, vol. xii.

On his return to England in 1903 Mr. Cookson installed his zenith telescope in a new building, and began a series of photographs which extended over four years. Five groups of stars were chosen, transiting near the zenith at nearly equal intervals of time, and so arranged that evening transits of one group could be photographed about the same epoch as morning transits of the next. The apparent change of latitude between evening and morning gave a correction to the assumed aberration constant; when this was determined, each group contributed to a determination of the variation of latitude. At Mr. Cookson's death this long and important series of photographs had been completely measured and reduced, but the discussion was unfinished. The duty of completing its preparation for press has been undertaken by colleagues at the Cambridge Observatory.

As his work with the zenith telescope approached completion, Mr. Cookson turned his attention to astrophysics, and in 1908 he was appointed to the newly created post of Assistant in Astrophysics at Cambridge. In conjunction with his uncle, Professor Newall, he then began the extensive laboratory researches on spectra, obtained under varying conditions, which were in progress when in 1909 June the illness began which caused his death, after much suffering, on 1909 September 13, at Hawick.

Mr. Cookson married, in 1907 December, Millicent, daughter of Mr. Thomas Elliot, of Sunderland, and leaves an infant son. His early death has robbed astronomy of one of the keenest and ablest of its younger workers.

He was elected a Fellow on 1894 December 14, and served on the Council from 1906 till his death.

Henry Zouch Darrah was born on 1854 August 1, at Landown, India. He was educated at Trinity College, Dublin, and entered the Indian Civil Service in 1877. He served chiefly in the United Provinces, but was lent to Assam as Director of Land Records and Agriculture, and was also sent on special duty in the Central Provinces and in Burmah. He was for some time Commissioner of the Allahabad District, till promoted to a seat

on the Board of Revenue. He was a well-known sportsman in India, Cashmir, and Somaliland. His writings include *Eleven Years' Work of a Land Records Department, The River-borne Trade of Assam*, and *Sport in the Highlands of Cashmir*. He was made a Companion of the Star of India in 1907.

He married, in 1887, Edith Isabel, third daughter of the late Fleming Hemdy, Esq., of Barraghcore, Co. Kilkenny, who survives him.

In the course of two voyages round the world he visited many of the principal observatories, but contributed no papers to the Society.

He died in London on 1909 March 18.

He was elected a Fellow of the Society on 1908 April 10.

Thomas Gordon, who came of an old Whitehaven family, was born in that town in 1844. About the year 1872 he began to take a keen interest in astronomy, and for many years he was a member of the Lunar Section of the British Astronomical Association, of which he was one of the founders. He possessed a small Cooke refractor and a 6½-inch Calver reflector, with which he made some drawings of the Moon which were published in the *Memoirs* of the British Astronomical Association.

He took an active interest in the Whitehaven Scientific Society, of which he was President in 1891 and 1892; was a keen numismatist, particularly interested in the Roman and British coins of his neighbourhood; and was a Fellow of the Royal Meteorological Society. He contributed no papers to the Society. He died on 1909 February 28, leaving a widow and daughter.

He was elected a Fellow on 1891 May 8.

Eugen von Gothard was born on 1857 May 31 at Herény, Hungary. He studied at the Gymnasium of Szombathely, and afterwards at the Polytechnische-Hochschule, Vienna, where he was distinguished for his work in mathematics and physics. On leaving the university he studied astronomy in various places, and especially worked in the observatory of his friend Nicolaus von Konkoly at O'Gyalla. Of independent means and delicate health, he decided in 1881 to build an astrophysical observatory at the family seat at Herény, and there he passed his life, unmarried, almost an ascetic, entirely occupied with his scientific pursuits. He was an early worker in celestial photography with the reflector, and the collection of the Society includes some excellent early photographs of nebulæ made by him. He published numerous papers on astrophysical subjects, particularly on the spectra of comets and of Nova Persei, and several popular works; and he contributed to the Society a paper giving an account of astrophysical work at his observatory in 1882 (*M.N.*, xliii. p. 425).

He was elected a member of the Hungarian Academy of Sciences in 1883. For the last five or six years of his life he suffered much; he died suddenly on 1909 May 29.

He was elected a Fellow of the Society on 1883 November 9.

Frederic Newton was born in 1824 at Hitchin. For fifty years he was the head of the well-known firm of Newton & Co., 3 Fleet Street, from which he retired about twelve years before his death. He was a member of the Worshipful Company of Spectacle Makers, and held various warrants as Instrument Maker to His Majesty the King and other members of the Royal Family, to the British, Indian, and Foreign Governments, and to the Royal Institution. For many years he held the office of Churchwarden at St. Dunstan's-in-the-West, was Treasurer of the Church Schools, and was a founder and honorary secretary of the Central Church of England Young Men's Society.

He contributed no papers to the Society. He died at his residence at Hornsey on 1909 October 3, at the age of eighty-four, leaving a son and two daughters.

He was elected a Fellow of the Society on 1877 April 13.

John Peter George Smith was born at Greenwich on 1818 October 16, the son of Mr. Lord Henry Smith, and a descendant of Dr. Miles Smith, Bishop of Gloucester 1612–1642.

He began life as a clerk in the Bank of England, leaving that position to join the firm of C. & J. Rawdon, merchants, of Liverpool. Later he became a Director of the Liverpool Borough Bank, and was afterwards in business in Liverpool from 1862 to 1871. In that year he started works at Jackfield, in Shropshire; and he lived in that neighbourhood, at Sweyney Cliff, until within a few months of his death.

He had always been a keen student of astronomy, and had worked under the late Mr. Hartnup at the old Liverpool Observatory in the Docks. In 1888, at the age of seventy, he mounted a refractor by Grubb at his house, and became a diligent observer, continuing his observations till within eighteen months of his death. It does not appear that he published any of his results, and he contributed no papers to the Society. In 1898 he visited India and observed the total eclipse at Talni.

Mr. Smith married his cousin Emma Juliana Gray, and had three sons and one daughter, of whom one son only survived him. He died at Weston-super-Mare on 1909 May 31.

He was elected a Fellow of the Society on 1891 January 9.

William Ford Stanley was born at Buntingford, Herts, about the year 1828. The son of a mechanical engineer, he was apprenticed to his father; and in 1854 he began business as an instrument maker, in partnership with his cousin, who, however, soon died. The foundation of his fortunes was the invention of the simple and inexpensive form of slide stereoscope. Soon afterwards great improvements in the construction and quality of drawing-instruments began to make the firm of W. F. Stanley & Co. well known; and, by continual care and remarkably hard work, its founder built up one of the largest and most successful businesses of its kind in the world.

Mr. Stanley was a man of great versatility. He was interested in many branches of science, an early worker in photography, an antiquary, a playwright, a painter, and a wood-carver. The wealth which he accumulated in the course of his successful business career was considerable; and in the latter years of his life he devoted much of his still great energy to devising a scheme by which he might permanently benefit South Norwood, where he lived, and where his factory was established. He designed and built a fine series of Halls and Art Galleries; and later he built and endowed the Trade Schools, which are designed to provide for selected boys from the elementary schools the education required to make them skilled craftsmen. In recognition of his public spirited munificence, Mr. Stanley was given the freedom of the borough of Croydon in 1907.

Mr. Stanley contributed no papers to the Society, but he published a work of a speculative nature, *The Nebular Theory*. His well-known treatise on *Mathematical Drawing and Measuring Instruments* is full of valuable information and of sound advice on the subject of which he was a master.

He died at Norwood on 1909 August 14, after a brief illness, leaving a widow, but no family.

He was elected a Fellow of the Society on 1894 February 9.

Henry Toynbee was born on 1819 October 22, at Heckington, near Boston, Lincolnshire, and at the age of fourteen entered the mercantile marine as a midshipman on the *Dunvegan Castle*. He soon obtained the appointment as third officer on one of the vessels of the famous line of East Indiamen owned by Messrs. T. & W. Smith, and eventually he commanded in turn several of the best-known vessels of that fleet.

Captain Toynbee was famous himself as a navigator, and trained a large number of the most successful navigators of his time, holding a navigation school daily on his ship. In particular he was an expert "lunarian," and he contributed several papers to the Society on the rating of chronometers by lunar distances. In 1854 he married a daughter of Admiral W. H. Smyth; she accompanied him on his voyages, and illustrated his well-known meteorological logs.

In 1866 Captain Toynbee left the mercantile service, and shortly afterwards he became Marine Superintendent of the Meteorological Office, where he did much excellent work, and published the *Barometer Manual* and many meteorological papers during his twenty-one years' service in the Office. In 1888 he retired, and devoted himself to his many philanthropic interests.

Besides the papers above mentioned, Captain Toynbee contributed to the information as to weather conditions in the Southern Ocean, which was collected by Sir George Airy in preparation for the Transit of Venus Expeditions.

His wife died in 1881, and they had no children. Captain

Toynbee died in London in 1909 April, within a few months of his ninetieth year.

He was elected a Fellow on 1854 February 10.

Jesse Young was a son of the late Richard Young, Esq., of Wisbech, Cambridgeshire, and Member of Parliament for the county, 1865–68. He spent the greater part of his life in Australia, and as astronomer to the party he took part in the Giles Expedition from Adelaide to Perth, Western Australia, in 1874.

He contributed no papers to the Society. He died at Perth, Western Australia, on 1909 October 8.

He was elected a Fellow on 1877 January 21.

George Washington Hough was born at Tribes Hill, Montgomery County, New York, on 1836 October 24. He received his early education at Waterloo and Seneca Falls, graduating with honours at Union College in 1856. Leaving college, he taught in the schools of Dubuque, Iowa, and at the same time prepared himself for the graduate course at Harvard University, where he stayed one year, taking the advanced mathematical and engineering course. He received his M.A. degree in 1859, and was shortly after appointed assistant to General O. M. Mitchell at the Cincinnati Observatory.

The Dudley Observatory, inaugurated in 1856, was planned under the supervision of Professor O. M. Mitchell, who finally left Cincinnati in 1860 to become its Director. Mr. Hough went with him, and on Professor Mitchell's death in 1862 succeeded to the post of Director. The first annual report was issued in 1862, and Mr. Hough continued the issue during his tenure of office. These reports are concise, but contain a large amount of information. From them one gathers that the astronomical and meteorological work engaged equally his attention, and he seems ever to have been inventing and making recording instruments for both departments. In 1866 Mr. Hough published a description of the observatory and of the instruments. Amongst these was a Swedish tabulating machine, concerning which a few words may not be out of place, as it probably may be accountable for bringing out the mechanical genius which he seems to have inherited from his father. The difference engine which Babbage was constructing for the British Government was never completed; but in the *Edinburgh Review* (1834 July), Dr. Lardner gave an account of it, which came under the notice of Mr. G. Scheutz, an eminent printer in Stockholm, who, having spent all his means on it, at length constructed a machine which was exhibited at the Royal Society in 1853. This machine was purchased in 1856 for the Dudley Observatory. Professor Hough evidently studied it and made some improvements. It gave direction to his mind, for we find him inventing a self-registering barometer by which the height of the mercury is printed hourly to thousandths of an inch, and the curve recorded on scales of 1 inch and 6 inches for the 24

hours. This instrument is described in vol. ii. of the *Dudley Observatory Publications*; it was made in 1865 and used continuously at Dudley. In 1876 Professor Hough received for it a gold medal at the Centennial Exhibition, and another at the World's Fair in Chicago. In 1869 he invented an anemograph for registering continuously the velocity and printing hourly the direction of the wind. Other mechanical inventions for recording observations are described in the same volume. From the Dudley report we also learn that he was much interested in various batteries, especially in the Daniell, being the first to suggest replacing the copper by lead. His storage battery seems to have been of a cheap and durable form.

In 1869 the Dudley Observatory fitted out a party of twelve observers for the solar eclipse. Professor Hough, using a 4-inch equatorial of $3\frac{1}{2}$ feet focal length, made the first exact record of the duration of the phenomenon known as Baily's Beads. About this time he was a Vice-President of the American Association for the Advancement of Science, and was elected a member of the Astronomische Gesellschaft.

Professor Hough continued as Director of the Dudley Observatory up to 1874, when for five years he devoted himself to commercial pursuits. In 1879, however, we find him in charge of the Dearborn Observatory of the Chicago Astronomical Society The observatory was without a chronograph, and it is characteristic of Professor Hough that he at once set about the invention and construction of a printing chronograph, which he presented to the observatory.

In his first year at Dearborn he commenced a study of the planet Jupiter, which he continued up to his death. The annual reports of the Chicago Astronomical Society contain a mass of his observations, the value of which is greatly enhanced in that they are made by one man throughout a period of thirty years. Professor Hough in 1867 had made a few double-star measures with the 13-inch refractor at Dudley; but at Dearborn he found Professor Burnham using the $18\frac{1}{2}$-inch refractor for double-star work; he became imbued with some of Burnham's enthusiasm for this branch of astronomical work, the result being measures of a large number of double-stars and the discovery of a large number of new ones. These discoveries are scattered in various astronomical journals; and this, added to their inherent difficulty, resulted in these pairs being neglected. Fortunately this is no longer likely to continue, as Professor Doolittle has collected them in one volume * with all the measures. One pair discovered by Professor Hough, viz., Ho. 212, 13 Ceti, has recently been found to have a period of 7·1 years, being the shortest known with the exception of δ Equulei (5·7 years). In 1865 Professor Hough invented a recording chronograph, which he brought to a high state of perfection in 1886. By an ingenious system of clockwork governed by electro-magnets, a

system of three type-wheels is made to print on a moving paper the minute, second, and 100ths of a second of an observation. The whole apparatus will stand on a table 18 inches by 24. An instrument of this type is now at the Durham Observatory.

In 1887 the Dearborn Observatory was removed to Evanston, Ill. Professor Hough, in addition to being Director, became also Professor of Astronomy in North-Western University. This Observatory will be an enduring monument to his memory. It was mostly planned by him, was equipped with his recording instruments, and the great dome was his invention. A bronze memorial tablet in his honour has been placed in the observatory.

Professor Hough, in addition to his theoretical ability, was an expert mechanic and made all his own instruments: he was always inventing. In 1891 he received the degree of Doctor of Laws from Union College. He was a member of many Societies.

Professor Hough was a quiet and unassuming man, much respected by his friends. His views were broad and his interests wide. Astronomy has lost one of its most ardent workers. His death occurred on 1909 January 1. He is survived by a widow and two sons.

He was elected an Associate of the Society on 1903 November 13.

T. L.

In Simon Newcomb the Society has lost one of the greatest of its Associates: a man worthy to rank with the great astronomers of all time. In 1895 he was elected one of the eight Foreign Associate members of the French Institute. This judgment might, perhaps, be questioned as that of a single nation only, but testimony of a world-wide kind was forthcoming in 1898, when the first Bruce Gold Medal was awarded by the votes of the Directors of the Berlin, Greenwich, Harvard, Lick, Paris, and Yerkes observatories: "One name stood forward so prominently in the communications from heads of six leading observatories of the world, that the Directors (of the Astronomical Society of the Pacific) could but set the seal of their approval upon the verdict of his peers, and award the first Bruce Medal to Simon Newcomb" (Address of the Pres. Ast. Soc. Pac.). His position in his own country was one of pre-eminence, not merely among astronomers but among men of all sciences; for in 1904 he was chosen President of the International Congress of Arts and Sciences which assembled at St. Louis.

He reached his pinnacle of greatness by his own efforts. Few men have had less sympathy and encouragement in their early years for talents which only seemed to indicate unfitness. "The skill required on a farm was above my reach, where efficiency in driving oxen was one of the most valued of accomplishments," he writes in his *Reminiscences of an Astronomer*. "I had, indeed, gradually formed, from reading, a vague conception of a different kind of world—a world of light—where dwelt men who wrote books, and people who knew the men who wrote books, where lived boys who went to college and devoted themselves to learning

instead of driving oxen. I longed much to get into this world, but no possibility of doing so presented itself." Into this world he did, however, ultimately make his own way with difficulty. His first venture was a lamentable failure—he hoped to study medicine under a famous physician, and found himself the drudge of a quack doctor, from whom he plucked up courage to fly. He walked fifty miles the first day, and after many hardships ultimately arrived at the coast, and worked his passage on a small sailing vessel to his father in Maryland. He became teacher in a country school (he was then nineteen) for two years, and afterwards in a private family near Washington. The story of his gradually finding his own way, through many hindrances and disappointments, to libraries, to the acquaintance of scientific men, and at last, in 1857, to the *Nautical Almanac* Office (then at Cambridge, Mass.), is graphically told in the autobiography above mentioned, and need not be repeated here. From that point his road was smoother, and remaining difficulties crumbled before his great ability and energy. But it may be doubted whether anything he has done since bears clearer witness to his qualities than his resolute escape from his unpromising beginnings.

Simon Newcomb was born at Wallace in Nova Scotia on 1835 March 12, a few months before the last visit of Halley's Comet; and he did not live to see the comet on its present return, dying at his home in Washington on 1909 July 11. On 1863 August 4 he married Miss Mary Caroline Hassler, granddaughter of the founder of the U.S. Coast Survey, and had several children. His daughter (Dr. Anita Newcomb M'Gee, who distinguished herself as a nurse in the Japanese war) kindly informs us that Newcomb's ancestors were one-fourth Scotch-Irish, one-eighth German, and the rest almost wholly English. All were on the American side of the Atlantic 150 years ago, and some since about 1614, having been a Huguenot family, the first known to have lived in the present New York City.

Newcomb did not remain many years at the *Nautical Almanac* Office in Cambridge, Mass., but while there he gave evidence of his mathematical powers by showing that the orbits of the asteroids had never passed through any common point of intersection, and that they could not therefore be fragments of an exploded planet, as suggested by Olbers. He also graduated B.Sc. at the Lawrence Scientific School of Harvard in 1858. On the breaking out of the Civil War, several of the U.S. Navy Professors of Mathematics resigned owing to the secession of their native States, and Newcomb was the first of those appointed to fill the vacancies (1861 September 21). We learn from Mr. Archibald's comprehensive bibliography (*Trans. Royal Soc. Canada*, xi., iii. p. 79) that he had up to this time published 17 papers and reviews of various kinds, and between this date and 1869, when he was elected to the National Academy of Sciences, there were a score of others, not only on such astronomical topics as the distribution of the orbits of the asteroids and the theory of Neptune, but on

economic subjects, such as "A Critical Examination of our Financial Policy during the Southern Rebellion." In 1869 he became aware of one of the problems which was to dominate his life, the Lunar Theory: the discordance of Hansen's tables, published in 1857, was already becoming apparent, and Newcomb wished to try his hand at detecting the reason. So he applied to be transferred from the Naval Observatory to the *Nautical Almanac* Office. The superintendent agreed to the work being done, but preferred to have it done at the observatory, and Newcomb accordingly remained in his appointment as observer. But he made a notable contribution to the research on which he had set his heart, almost at once. It occurred to him that there might be, available for extending the data used by Hansen, occultations of stars by the Moon in the years before 1750, recorded in the observation books of the Paris Observatory, but not hitherto published. His successful search for them was a dramatic incident. When the idea first occurred to him the Franco-Prussian war was going on and he could not visit Paris; and when in March 1871 he entered it by "almost the first train that passed the German lines," he spent six weeks at the observatory while "the city was under the reign of the Commune and besieged by the national forces. The studies had to be made within hearing of the besieging guns." But the search was triumphant; an abundance of occultations had been observed (though apparently with no particular object in view at the time), and the "history of the Moon's motion was extended back from 1750 to 1675, and, with a less degree of accuracy, thirty years farther still. Hansen's tables were found to deviate from the truth in 1675 and subsequent years to a surprising extent; but the cause of the deviation is not unfolded even now." The interest thus roused in the tables of the Moon naturally extended itself to those of the planets; and when (in 1877) Newcomb was appointed Superintendent of the *American Ephemeris*, he devoted himself for a quarter of a century, "with all the force he could spare, to the work of deriving improved values of the fundamental elements and embodying them in new tables of celestial motions." "This gigantic purpose," writes Ormond Stone, "he lived to see completed as far as the major planets were concerned." Reserving for his own consideration the four inner and the two outer planets, he assigned the orbits of Jupiter and Saturn to Dr. G. W. Hill. The results for the four inner planets were published as a supplement to the *American Ephemeris* for 1897, and it was found that observed discrepancies could be accounted for by assuming a ring of matter lying between the orbits of Mercury and Venus, though Newcomb did not lay much stress on the hypothesis.

But this is anticipating. Before he left the U.S. Naval Observatory for the *N.A.* Office he took a prominent share in three great enterprises, to each of which he devotes a chapter of his *Reminiscences*. It was determined to erect a large telescope at the observatory, and much of the consequent work fell to Newcomb, who saw it completed and worked with it to good purpose before

handing it over, on his departure from the observatory, to Asaph Hall, who discovered the satellites of Mars with it. This sensational result of the erection of the telescope is well known ; it is not so well known how Newcomb had tried to obtain such an instrument and failed until the accidental visit of the young son of Mr. Cyrus Field, and his report at his father's dinner-table of the poor equipment of the observatory startled some influential people into action.

The second of the three chapters above mentioned deals with the transits of Venus. Newcomb's work in discussing the old transits (in the course of which he dispersed the cloud of suspicion under which the memory of Father Hell had lain for a century) and in organising that of 1874 was of the first order. On the unfavourable results becoming known, he and E. C. Pickering voted against any great expedition in 1882, but were overruled, and Newcomb thereupon took charge of the expedition to the Cape of Good Hope.

The third chapter is on the Lick Observatory. Newcomb was consulted in 1874, and visited Europe to see what prospects there were of glass for the lenses. He also nominated the first director of the observatory, E. S. Holden. He mentions some interesting correspondence with Mr. Lick, "who did not see why so elaborate and expensive a mounting as that proposed was necessary, and thought that the object-glass might be mounted on the simplest kind of a pole or tower which would admit of its having the requisite motions in connection with the eyepiece." He suggested also the trial expedition of S. W. Burnham to the mountain-top, which produced the report of 42 first-class nights, and only 7 classed as low as medium. Newcomb himself visited the summit for three nights.

Meanwhile his reduction of the lunar observations collected in Paris occupied him for six years (1871–77) and was published in 1878. He then settled down to the great work on the planets and the direction of the American *Nautical Almanac* Office. He had already (in 1874) been awarded our Medal for his researches on the orbits of Neptune and Uranus, and the President of the day, Professor Cayley, drew attention to various other researches of importance, especially a theoretical memoir on the problem of three bodies, which he characterised as being, "from the boldness of the conception and the beauty of the results, a very remarkable one, constituting an important addition to theoretical dynamics." Thus Newcomb was well equipped for the work before him—probably better than any man of his generation. There was an immense amount of labour ahead : "it seems hard upon the maker of a set of planetary tables," said Cayley in 1874, "that he should not at least have, ready to hand for comparison with theory, a single and entire series of observations of the planet. . . . I cannot help thinking that there should be some confederation of observatories or central calculating board for publishing the lunar and planetary observations, etc., reduced to a concordant system." The needed

uniformity is not yet attained, but what progress has been made towards its attainment is largely due to Newcomb himself, and he was doubtless stimulated to action in this direction by the great labour of reducing existing observations to a homogeneous system. He was led incidentally to the formation of a great fundamental catalogue of 1098 stars, and the adoption of a set of fundamental constants. Accounts of this great work have appeared from time to time in our Council Reports (see, for instance, *M.N.*, lvi. p. 267).

Newcomb was superannuated in 1897, but his activities suffered no diminution. He returned to the lunar theory, and had the great satisfaction of completing his survey of the existing state of the problem before his death. His conclusions are summarised in a paper contributed to the *Monthly Notices* just a year ago, and illustrated by a striking diagram. He finds that there are outstanding fluctuations, and writes:—

"I regard these fluctuations as the most enigmatical phenomenon presented by the celestial motions, being so difficult to account for by the action of any known causes that we cannot but suspect them to arise from some action in nature hitherto unknown. . . . At present I see nothing more to do than to invite the attention of investigators to this most curious subject."

But he also turned his attention to solar physics, and inquired whether the periodicity of the solar activity is strict, or only approximate, deciding in the former sense. He went on to an investigation of our weather, and reached the conclusion that all the phenomena of temperature, rainfall, and winds are due to purely terrestrial causes, and that no changes in the Sun's radiation affect them, except perhaps a fluctuation of 0°·2 C. in temperature with the sun-spot period (*Trans. Am. Phil. Soc.*, n.s., xxi., pt. v. p. 379). But the work of Mr. C. G. Abbot on solar radiation, published at about the same time, does not altogether confirm these views.

It is impossible to give a complete account of Newcomb's activities in a brief notice such as the present. His great works, such as the *Astronomical Papers of the American Ephemeris*, are too well known to need enumeration. The publication began in 1882, but some of the papers are of earlier date. The bibliography of Mr. Archibald tabulates the titles of 376 papers and writings, including several books. His *Popular Astronomy* has been widely known for many years, and was translated into German, Russian, Norwegian, Bohemian, Dutch, and Japanese. A recent work, *The Stars: a Study of the Universe*, is of no less merit. His own *Reminiscences* (Houghton Mifflin, 1903), from which many quotations have been made above, is a mine of wealth in scientific history. His chief work was, of course, the collation of observations of the Moon and planets, so as to rectify the tables: but he also wrote novels, and text-books on finance; articles on labour and currency questions, and on theology. A text-book on algebra, which his daughter was studying, appeared to him so unsatisfactory that he wrote her out a series of lessons himself, which were then

collected into a successful schoolbook, followed in due course by others on trigonometry and the calculus. His textbook, *A Compendium of Spherical Astronomy*, published in 1906, is a most valuable work of reference.

His Presidential Address in 1904 to the International Congress of Arts and Sciences on "The Evolution of the Scientific Investigator" afforded a striking example of the breadth of his outlook, his conception of the meaning of Science, and his divination of its true origin.

"The true man of science has no such expression in his vocabulary as 'useful knowledge.' His domain is as wide as nature itself, and he best fulfils his mission when he leaves to others the task of applying the knowledge he gives to the world." "While giving all due honour to the great inventors, let us remember that the first place is that of the great investigators"—by such words as these he declares his faith in the true nobility of modern scientific investigation. His idea of its origin is indicated by the names of the men to whom he gives precedence—Luther, Copernicus, Leonardo, Columbus, and Gutenberg, all born in the fifteenth century; and his reasons, if not sufficiently obvious from the association of the names, will be clear enough from the terms in which he speaks of one of them:—"Luther, the greatest thought-stirrer of them all, ... does not come in as a scientific investigator, but as the great loosener of chains which had so fettered the intellect of men that they dared not think otherwise than as the authorities thought." The highest place was assigned by Newcomb to these men because of his conviction that their existence was vital, that the course of events after them differed from that before them "as a living tree from a dead one": with a difference like that made by a "drop of blood in the wrong place, which some one has told us makes all the difference between a philosopher and a maniac." No one was more ready than Newcomb to "banish cataclysms to the theological limbo, and view nature as a sleepless plodder," but he is emphatic in reminding us that this is not the whole truth. "The building of a ship, from the time that her keel is laid until she is making her way across the ocean, is a slow and gradual process, yet there is a cataclysmic epoch opening up a new era in her history. It is the moment when, after lying for months or years a dead, inert, immovable mass, she is suddenly endowed with the power of motion, and, as if imbued with life, glides into the stream, eager to begin the career for which she was designed."

Thus Newcomb stated his conviction that the fifteenth century was such a cataclysmic epoch in the history of the human race. This public utterance at the summit of his career gives us the key to his own personality; he was not only a great astronomer, not only a great man of science, but also an apostle of freedom of thought in all directions, a worthy and eminent representative of modern experimental science. His sympathies with enterprise were wide; witness his becoming first President of the American

Society for Psychical Research in 1885. He loved to shake off limitations; we have seen how he broke the fetters which had bound accepted lunar observations, and adding a century to their extent. When Küstner and Chandler announced a variation of latitude to a sceptical world of theoretical astronomers, it was Newcomb who first freed his thoughts from old traditions sufficiently to find the theoretical clue. Sometimes he carried his wish for the removal of limitations to lengths where others could not follow him. When photographs of the nebulosity round Nova Persei showed that *something* was moving with great velocity, Newcomb was quick to welcome the overstepping of limits hitherto assigned to the velocity of celestial motions, and was frankly disappointed when another explanation was forthcoming in the travelling of illumination merely. It may be surmised that when, at the end of his life, he found that the Moon refused complete allegiance to the law of gravitation, so far as he could determine the circumstances, he rather rejoiced in the rebellion, though he yielded to none in his respect for the majesty of that law.

His visits to Europe were frequent, and he was a welcome friend in all the great cities, where he was generally either an honorary graduate of the University or a Foreign Associate of the society or academy. He was elected a Foreign Associate of this Society in 1872; of the Royal Society in 1877; of the Royal Institution at the Faraday Centenary in 1891. He received our Medal in 1874, and the Copley Medal of the Royal Society in 1890. He was passionately fond of the Swiss mountains. At one time it seemed as though his climbing were at an end, for he was apparently crippled, though he had undergone two severe operations in hope of cure. Ultimately Dr. Putnam cured him by psycho-therapy, and he was able to resume his climbing, to his great delight. It was only shortly before his death that serious trouble returned, the seeds of which may have existed in the former time. He did not escape long months of agony, heroically borne, but worked to the end at his lunar computations. It was a touching mark of the regard in which he was held that the naval surgeon who attended him regularly (he had, of course, specialist advice also), and who had reached the age for retirement, was continued in his office on full pay, by order of the Secretary of the Navy, "so long as Professor Newcomb needed him." At his death, in July, Newcomb was accorded a military funeral, with the rank of Rear-Admiral, which had been granted by a special act of Congress three years before. H. H. T.

Proceedings of Observatories.

Royal Observatory, Greenwich.
(*Director, Sir William Christie, K.C.B., Astronomer Royal.*)

Transit-circle.—During the year 8970 observations of transits and 8781 of meridian zenith distances have been obtained. The Sun has been observed 156 times and the Moon 114 times. The lunar crater Mösting A has also been observed 61 times. Reflexion observations of stars have been obtained on 71 nights.

In order to facilitate the reduction of the next Greenwich Catalogue to any fundamental system that may ultimately be adopted, it was decided that, starting with 1910 Jan. 1, 6 stars from Newcomb's Fundamental Catalogue, and comprised within the limits Dec. + 24° to + 32° of the zone under observation, should be observed each night. In this way material will be provided for a complete re-reduction of the observations of the zone, if that should at any time become desirable.

Altazimuth.—This instrument has been used, as before, as a meridian transit instrument during the second and third quarters of the lunation for the observation of the Sun, Moon, planets, and the stars in Newcomb's Fundamental Catalogue. The instrument is reversed every two months, alternately by reversing in its Ys and by turning the instrument through 180° of azimuth.

The total number of meridian transits obtained during the year is 1491, including 85 of the Moon's limbs and 37 of the lunar crater Mösting A. 85 reflexion observations of stars have been obtained. The number of extra-meridian observations of the Moon obtained during her first and last quarters is 48.

A working list has been made of stars selected as reference stars for the photographs of Mars obtained with the Thompson Equatorial, and these are being observed on the meridian. The object of the photographs is to obtain a uniform series of positions of Mars over a longer arc than is possible with a meridian instrument.

The central object-glass illumination has been normally employed; on several fine nights, when the instrument was in the meridian, some clock stars and standard polars were observed with the field illuminated by the annular reflector in the axis. The following differences between clock errors with the two methods of illuminating the field have been found since 1908 September, and up to 1909 November 15:—

Observer.	No. of Nights.	Central Illum. − Annular Illum.
A.C.	10	0·00
H.F.	8	+0·01
Other observers,	13	+0·03

The observations of stars made with the Altazimuth for the ten years 1899–1908 are being combined into a Ten-Year Catalogue. It will contain nearly 2000 stars, consisting of Newcomb's funda-

mental stars, Eros comparison stars, Zodiacal stars, and stars selected for special purposes, especially for reflexion observations north of the zenith.

Reflex zenith tube.—During the year 1302 double observations and 13 single observations of stars have been obtained. γ Draconis was observed on 65 days, β Draconis on 45 days, ι^2 Cygni on 44 days, and θ Ursæ Majoris on 20 days.

It had been found that, owing to obstruction by the annular reflector used for illuminating the field of view, the full aperture of the object-glass was not being used when stars at a considerable distance from the centre of the field were observed. A modified form of reflector devised to obviate this was brought into use on January 20, in conjunction with a rheostat to control the intensity of the illumination.

Occultations.—During the year 19 disappearances and 15 reappearances of stars occulted by the Moon have been observed by one or more observers. The results have already been communicated to the Society.

28-inch Refractor.—579 double stars were measured during the year; they may be classified as follows:—

87	pairs	under	0″·5 separation.
152	,,	between 0·5	and 1″·0 separation.
139	,,	,, 1·0	,, 2 ·0 ,,
201	,,	over	2·0 separation.

κ Pegasi was observed on 7 nights, δ Equulei on 8 nights, and 70 Ophiuchi on 13 nights.

Measures of the polar and equatorial diameters of Mars were made on 15 nights.

Measures of the diameters of the ball and rings of Saturn were made on 8 nights.

Thompson Equatorial.—With the 26-inch refractor the following photographs have been obtained:—

Jupiter, for position,	7	photographs on	6 nights.
Saturn ,,	4	,,	2 ,,
Mars ,,	29	,,	14 ,,
Mars, with enlarging camera,	6	,,	3 ,,

With the 30-inch reflector the following photographs have been obtained:—

Jupiter *vi.*,	27	photographs on	22 nights.
,, *vii.*,	7	,,	7 ,,
,, *viii.*,	17	,,	16 ,,
Saturn *ix. Phœbe*,	10	,,	7 ,,
Comet *a* 1909,	8	,,	8 ,,
b 1909,	9	,,	8 ,,
c 1909 (Halley),	29	,,	18 ,,

and 56 photographs of 26 minor planets.

All the above were taken for position.

In addition, 22 long exposures were made with the 30-inch reflector on the region near Mars. Three faint objects were found quite near the planet, but all proved to be minor planets moving at about the same rate as Mars.

Five new minor planets in all were discovered during the year, namely, FN, HB, HR, HS, and HT. Besides these, a planet JC was found, which was afterwards identified with (50) Virginia, for which the ephemeris was considerably in error.

The photographs of Jupiter's Satellites *vi.*, *vii.*, and *viii.*, and of Jupiter for position, have been measured and the results published. An orbit of the eighth satellite, determined by Messrs. Cowell, Crommelin, and Davidson, has been published in the *Monthly Notices.*

The observations of minor planets for 1908 have been communicated to the Society.

Considerable progress has been made with the measurement and discussion of the photographs of Comet Morehouse for the determination of the motions of the matter forming the tail.

Messrs. Cowell and Crommelin's final predicted value for the date of perihelion of Halley's Comet was 1910 April 16·57 G.M.T. The actual value will be very close to April 19·6394, which has been deduced by Mr. C. J. Merfield from observations extending from 1909 September to December. The discordance between the predicted and actual dates is thus 3·07 days. In order to determine whether any part of the discordance was due to arithmetical errors, a re-computation of the perturbations for the years 1823 to 1847 has been partly carried out, this being the region of the large perturbations by Jupiter. In the new computation the time intervals have been taken half as large as before, as it appeared that when the comet was near the Sun or near Jupiter the previous intervals were rather too large. A few unimportant arithmetical errors were picked up in the revision; probably their combined effect on the period does not exceed one day.

Astrographic Equatorial.—Work with the 13-inch photographic telescope has been mainly confined to replacing chart plates which, though satisfactory in other respects, are, owing to slight photographic defects, unsuitable for production of enlarged prints.

During the year 55 chart plates have been taken and 25 miscellaneous fields. Of the 55 chart plates 13 were rejected, 3 because the exposure was interrupted by cloud, and 10 for miscellaneous faults. The 25 plates consisted chiefly of photographs of fields round minor planets, and of fields of stars about the orbits of Jupiter and Saturn which were necessary for determining the positions of the satellites of these planets.

Enlarged prints of 217 chart plates have been made and distributed during the year, bringing the total number reproduced to 1154. The whole Greenwich zone of 1149 fields is thus completed, the region immediately round the Pole being represented by 6 different prints, taken in different orientations, and at different dates, for comparison.

The computing work of the department has consisted mainly in the preparation of the Catalogue of Right Ascensions and Declinations of the Stars which will form part of volume iii. It was mentioned in the report of last year that the positions of 2100 stars of Carrington's Catalogue had been formed from the measured co-ordinates in the Astrographic volume. In continuation of this, during the year 1909, the R.A. and Dec. of the remaining 1635 stars of that catalogue and of about 3550 stars of the Kasan Zone of the Astronomische Gesellschaft Catalogue have been computed. As the Kasan Catalogue covers the zone of declination 75° to 80°, and Carrington's Catalogue the region from declination 81° to the Pole, in order to supply stars of magnitude between nine and ten and between declination 80° and 81°, which would otherwise have been wanting in the catalogue, the positions of all the stars of the Bonn Durchmusterung which are included in zone 80° of the Astrographic Catalogue have been similarly computed. The computation of right ascension and declination is thus complete from the Pole to declination 76°, and for the stars of declination 75° from R.A. 0^h to 12^h. The total work for the past year amounts to the determination of the positions of about 5600 stars, involving the conversion of the measured co-ordinates of more than 12,900 images.

The numbers of stars shown with different exposures, measured and counted in small areas of the sky, have been re-arranged in zones and areas of galactic latitude and longitude. The full tabulation of this will be given in volume iii.

A report on the progress of the work, with an evaluation of probable errors of results, was made, and presented at the meeting of the Permanent International Committee which took place at Paris in April.

Photoheliograph.—Photographs of the Sun have been taken on 199 days during the year 1909. Of the photographs, 418 have been selected for preservation, including 23 with double images of the Sun for determination of the zero of position of the wires.

Photographs have been received, through the Solar Physics Committee, from Dehra Dûn, India, up to 1909 November 3, and these have been further supplemented by photographs from the Observatory of Kodaikánal, India, the last photograph from which is dated 1909 August 30. The daily record thus made up is complete for the year 1909 up to November 3—the date of the last photograph received from Dehra Dûn—with the exception of August 1, for which no photograph is at present available. The photographs taken at Greenwich have been measured up to the end of 1909, those from Dehra Dûn up to 1909 June 12, and those from Kodaikánal as far as they have yet been received.

The work of measuring fresh photographs in the years 1906, 1907, and 1908, and of their subsequent reduction, rendered necessary by the disturbance of the adjustment of the Dehra Dûn photoheliograph, has now been completed, and the arrears of computation and publication entailed thereby are being rapidly over-

taken. For the year 1906 the complete photoheliographic results have been printed. For the year 1907 the daily results are ready for the printer, and the ledger of spot-groups has been finished. For the year 1908 the computation of the heliographic co-ordinates of the spots and faculæ has been completed, and the copy for press of the daily results prepared as far as August 7. For the year 1909 the computation of the heliographic co-ordinates of the spots and faculæ has been completed for the Greenwich photographs, and for the Kodaikánal photographs so far as the latter have been received, *i.e.* up to August 30, and for the Dehra Dûn photographs up to March 23.

During the year, Mr. Hough has sent the photoheliograph of the Cape Observatory to Greenwich in order that it might be adapted to take photographs of the Sun on the scale of a decimetre to the solar radius. The necessary alterations have been made, and it has been received back safely at the Cape Observatory, and daily photographs of the Sun will be taken with it under Mr. Hough's superintendence, to fill up, as far as practicable, the gaps in the Greenwich series.

The solar activity in 1909 showed a decline as compared with 1908, but only to a slight amount.

Mr. Maunder returned to the observatory from absence on sick leave on March 19, but had again to be granted sick leave from May 11 to June 12.

Longitude Determination.—Owing to a discrepancy amounting to over 1^s between the longitude of Malta as determined by the Hydrographic Office and a determination by Auwers and Gill, "German Transit of Venus Expedition" 1875, a direct determination of the longitude was made in the spring of 1909. The electrical arrangements were generally similar to those used in the determination of longitude Greenwich–Ascension–Cape, and the signals were transmitted directly between Porthcurno and Malta without a relay. The Eastern Telegraph Company again kindly gave the free use of a cable for the exchange of signals. At Malta, the pier and observing hut were erected on the roof of the Eastern Telegraph Company's offices at St George's Bay.

The observations were made by Mr. Eddington and Mr. Harold Christie; they were divided into two parts; the observations for the first part were made from February 20 to March 8; the second part was started on May 8, being greatly delayed by an interruption of the cable, and was finished on May 16. Corresponding observations at Greenwich and Malta with exchanges of signals were made on 6 nights in the first part and on 6 nights in the second part.

The reduction of the observations is in progress.

Printing.—At the end of the year the following works were being distributed:—

Greenwich Observations for 1907.
Astronomical Results for 1907.
Magnetical and Meteorological Results for 1907.
Photoheliographic Results for 1906.

Second Nine-Year Catalogue, 1900.
Precession Tables for the Third Ten-Year Catalogue.
Catalogue of Recurrent Groups of Sun-Spots 1874–1905.

The printing of the Greenwich Observations for 1908 is well advanced.

Royal Observatory, Cape of Good Hope.
(Director, Mr. S. S. Hough, H.M. Astronomer.)

Transit-Circles.—The meridian observations throughout the year have been principally devoted to the formation of the catalogue of fundamental stars with the new reversible transit-circle. The observations, as in previous years, have been conducted by the Repsold-Struve method with hand guiding. Designs have, however, been prepared, and an order placed with Sir Howard Grubb for the construction of a clock movement and differential gear, which, it is hoped, will be ready for installation on the completion of the current working list.

The observations with the new transit-circle include also regular observations of the Sun and inferior planets, and of the lunar crater Mösting A in conjunction with similar observations at Greenwich.

The old transit-circle has been used for occasional time determinations and observations of the lunar crater Mösting A.

The number of observations secured with these instruments during the year was as follows:—

Observations of Right Ascension:—

	Reversible T.C.	8-in. T.C.
Number of Meridian Transits .	7582	324
Determinations of Collimation by collimators	139	52
„ by reflexion and reversal	31	
Determinations of Level . .	706	67
„ Azimuth . .	286	26
Observations of N. Azimuth mark	1161	
„ S. „	1167	

Observations of Zenith Distances:—

Determinations of Z.D. . .	7179	76
„ Runs . .	401	19
„ Nadir . .	715	20
„ Flexure . .	55	12

The observations with the reversible transit include observations of the Sun on 124 days, of Venus on 85 days, and of Mercury on 55 days.

The lunar crater Mösting A has been observed on 27 nights with the reversible transit-circle, and on 14 nights with the old transit-circle.

Heliometer.—The observations of major planets at the time of opposition have been continued and the following secured :—

Opposition of	Neptune	64	obs. on	6	nights.
,,	Jupiter	50	,,	7	,,
,,	Uranus	52	,,	8	,,
,,	Mars	52	,,	7	,,
,,	Saturn	48	,,	6	,,

91 observations of distances and position-angle of Comet Morehouse (*c* 1908) relative to neighbouring stars were obtained, together with 20 observations of pairs of stars for the determination of instrumental constants.

The Victoria Telescope.—This instrument has been employed throughout the year on the photography of stellar spectra.

Observations were made on 181 nights, and 400 plates secured.

In addition to the stellar plates, 84 "daylight" plates were taken along with the comparison spectrum as reference plates for the stellar spectra, and 41 plates for control of the focal adjustments.

Astrophysical Laboratory.—A machine constructed on a new design for measuring the wave-lengths of the lines in stellar spectra was made in the workshops of the observatory, and has been successfully employed in the determination of radial velocities, the accuracy of measurement being not inferior to that of other types of spectrometers, while the work of reduction is considerably reduced. Altogether 740 star—with solar comparison—plates were measured in this apparatus and reduced. Of these, 214 represent observations of stars used in the determination of solar parallax, but observed outside the adopted limits of epoch of quadrature, and for this reason omitted from the investigation published in Cape Annals, vol. x. part 3. The remaining 526 plates relate to stars in the present working programme prepared with a view to the examination of the systematic motions of the stars in the line of sight.

A preliminary discussion of the results of these measures, in conjunction with such results of other observatories as were accessible, was submitted to the R.A.S. in November.

The main facts brought to light appear to be confirmatory of the two-drift hypothesis first put forward by Kapteyn, but require a slight extension of this hypothesis with respect to the distribution of the stars in the two drifts. Later investigations show that this modification will go far to account for hitherto unexplained anomalies in the determination of the precessional constant.

Besides these plates, 430 plates of stars contained in the earlier working programme, other than those used for the parallax determination, have been measured in the Hartmann spectro-comparator and 4 plates of the planet Mars in the Toepfer micrometer.

A detailed discussion of these measures is in course of preparation for press.

Astrographic Telescope.—This instrument has been chiefly used in the continuation of the programme of the photography of Kapteyn's selected areas, and the occasional repetition of plates involved in the *Carte du Ciel* programme.

An interesting series of plates of Comet Morehouse taken after perihelion passage was also secured.

Details of the plates obtained during the year are as follows :—

	No. of Plates.	No. of Exposures.	Duration of Exposure.
Kapteyn areas, proper motion plates .	12	24	20^m, 20^m
Kapteyn areas, parallax plates (1st max.)	82	82	20^m
,, ,, ,, (2nd max.)	134	268	20^m, 20^m
,, ,, ,, (3rd max.)	70	70	20^m
Catalogue plates	38	114	6^m, 3^m, 20^s
Comet Morehouse	18	18	various
Halley's Comet region	1	3	100^m
Adjustments	3	...	various

Of the Kapteyn *selected area* plates, 104 taken during 1909, or in previous years, have been forwarded to Professor Kapteyn, who will make provision for measuring the same.

Astrographic Laboratory.—In connection with the *Carte du Ciel* programme, 113 plates containing about 70,000 stars have been completely measured and the rectangular co-ordinates reduced. In the case of 110 plates, however, the reductions have not yet been completely examined. Six plates measured in previous years have been since rejected on account of abnormal errors in the plate-constants, insufficiency of stars or similar causes. All the plates of the revised series have now been measured with the exception of three, which require to be repeated *ab initio*, and which will be secured as early as the regions are accessible in the present year.

The plate constants have been derived for 712 plates during the year, completing these determinations for all plates already measured.

An experimental application of the plate-constant corrections and intercomparison between overlapping regions taken on different plates has brought to light certain hitherto unexpected anomalies affecting the plate-constants, which form the subject of a special report to the Permanent Committee of the International Astrophotographic Congress.

Occultations.—Twenty-three separate phenomena of occultations have been observed, viz.—

Disappearances of stars at dark limb .	10
Reappearances ,, ,, ,, .	13

Photoheliograph.—Provision having been made for the daily photography of the Sun in order to supplement the series of

Greenwich photographs, the Dallmeyer photoheliograph was dismounted and forwarded to England for overhaul in March. After being fitted with a new enlarging lens and camera, the instrument was returned to the Cape and received back in December. Regular observations with it will be commenced early in the present year.

Geodetic Survey of South Africa.—The outstanding reductions of the N.E. Rhodesian Survey have been completed during the year; the whole has been prepared for press and forwarded to England for publication.

Miscellaneous.—The time-signal service, meterological observations, and seismograph records have been maintained as in previous years.

Royal Observatory, Edinburgh.
(*Director, Prof. F. W. Dyson, Astronomer Royal for Scotland.*)

No observations have been made with the transit-circle except for the time service. The observations for the Zodiacal Catalogue have been re-reduced, using as a basis the positions of stars in Professor Boss' Catalogue, which were kindly communicated in advance of the publication of that work.

For the spectroscopic determination of the Sun's rotation, photographs have been taken on 44 days. About half of these photographs have been measured.

During the year 40 astrographic plates in Zone $-40°$ have been measured. Two images of each star are measured, one in the direct and the other in the reversed position of the plate in the micrometer. The total number of stars measured is 24,777, and has varied from 251 to 1457 per plate. The measurement in Zone $-40°$ is now completed for the plates whose centres are at 0^h to 8^h 0^m, 9^h 40^m to 10^h 30^m, 11^h 40^m to 12^h 10^m, and 13^h 40^m to 15^h 30^m. Copy for press has been made for the first six hours.

With the 15-inch refractor double-star observations have been carried on, especially during the latter part of the year. Measures of 320 stars have been made, about half of them on two nights and the remainder on one night only. The distance apart of the two components is less than $1''.0$ in 51 cases. The stars all lie between Dec. $+50°$ and the North Pole.

Seismographic observations have been carried on continuously with an instrument of Professor Milne's pattern. The records have been greatly improved this year by the use of an enlarged time scale. Meteorological observations have also been carried on regularly.

Mr. Clark left the observatory on January 11, Mr. Storey was promoted on March 19, and Mr. Wrigley appointed to succeed him on July 27.

Cambridge Observatory. (*Director, Sir R. S. Ball.*)

1. *Meridian Circle.*—The year 1909 has been unusually cloudy. Mr. Hartley resumed the observation of Gill's Catalogue of Zodiacal Stars in the spring, and has observed 1176 stars on 32 nights, with the necessary determinations of instrumental corrections. The reductions to apparent place are computed to 1907 August 29 in Right Ascension, and to 1909 April 5 in Declination; the reductions to mean place are computed to 1907 August 29.

The large volume of ledger of observations for the Cambridge Zone Catalogue, now in the press, is printed as far as R.A. $12^h\ 4^m$.

The model time-ball mentioned in the last report is now installed, and can be dropped from the Graham mean time clock, which is adjusted daily to G.M.T.

2. *Sheepshanks Equatorial.*—In continuation of the series for stellar parallax, a number of plates to complete series have been taken by Mr. Hinks during the year. Seven series have been measured, principally by Mr. Campbell, and the reductions are in a forward state.

Mr. H. N. Russell reports that the measurement and reduction of the large number of plates taken by himself and by Mr. Hinks during the years 1904–1907 are now complete. The results have been communicated in advance to Professor Kapteyn.

During the summer vacation Mr. A. H. Joy, Director of the Observatory of the Syrian Protestant College, Beirut, worked for several weeks with the instrument, and began an investigation of some problems in photographic photometry.

3. *Reduction of Eros photographs for determination of the Solar Parallax.*—This work, which has been in progress for a number of years, is now almost complete. The principal results were communicated to the meeting of the *Comité Permanent de la Carte du Ciel* at their meeting in Paris in 1909 April, and an extensive report is published in the *Procés Verbaux* of the Conference. Further details are given in Solar Parallax Papers No. 7 (*M.N.*, 1909 May). A new determination of the mass of the Moon from the photographic observations has been completed, and is published in Solar Parallax Papers No. 8 (*M.N.*, 1909 November). The discussion of the micrometric observations is nearly complete, and preliminary results were communicated to the Paris Conference.

The photographic standard Catalogue of Comparison Stars has been improved by the addition of the results from the Algiers Observatory, kindly communicated in manuscript by M. Gonnessiat; and by a new reduction of the Toulouse observations, communicated by M. Baillaud, Director of the Paris Observatory. Two-thirds of the manuscript of the body of the catalogue is in the hands of M. Baillaud, and its printing will begin shortly. The manuscript of the remainder, and of the extensive introduction, is in a forward state.

Mr. Hinks has been assisted in the card catalogue work and in the preparation for press by Mr. S. E. Bowd, and the expense of this assistance has been defrayed, as in former years, by a grant from the Government Grant Fund of the Royal Society.

4. *Floating Zenith Telescope.*—The illness and lamented death of Mr. Cookson brought his work with this instrument to a close at the moment when his long investigation of the variation of latitude and the aberration constant was complete as to observation, and measurement of the plates, and when the discussion was in active progress. The whole of the papers have recently been placed in the hands of Mr. Stratton, who hopes to be able to complete the preparation for publication without serious delay.

5. *Reduction of Lunar Observations.*—Mr. Stratton has completed his new reduction of Schlüter's heliometer observations of Mösting A, and his "Constants of the Moon's Physical Libration" is published in the *Memoirs* of the Society (vol. lix. part iv.).

6. Courses of instruction in practical astronomy, and in field astronomy for surveyors and geographers, have been given by Mr. Hinks during the year.

The Newall Telescope, Cambridge Observatory.
(*Professor H. F. Newall.*)

The year is sadly marked by the death of Mr. Bryan Cookson, Assistant in Astrophysics,—a worker of unusual power and promise, and a helpful companion.

The work of the past year has related chiefly to solar observations and the experimental study of spectra in the laboratory.

With the Newall Telescope various observations have been made for the purpose of getting information needed for remodelling the stellar spectrograph. Halley's Comet was seen on the night of October 21, close to the position indicated by the ephemeris of Messrs. Cowell and Crommelin. Preparations were made to photograph its spectrum with a slitless spectrograph, but it has proved hitherto too faint and diffuse. Visual observations have failed to disclose any discontinuity in the blue, green and red regions of the spectrum; nothing but continuous spectrum has been seen. A spectrograph with slit is now ready for study of the spectrum when the comet becomes a brighter object.

Solar observations with the Littrow spectroscope have been seriously hampered by the unfavourable weather conditions of the past year. Mr. Hubrecht continues his work in this line of research.

The perfecting of the new image lens, with aperture 12 inches and focal length 60 feet, has been delayed by defects in the flint glass. In the state in which it was first received from Jena it was worked by Messrs. T. Cooke & Sons of York, but the final optical tests showed that the flint lens was irregularly defective in homogeneity. It was re-annealed at Jena and re-worked at York;

and though the homogeneity has been considerably improved, the performance of the finished lens is inadequate for the researches in which it is to be used.

The spectroscopic work in the laboratory was carried on by Mr. Cookson up to the time of his illness. The valuable observations that have been obtained will be continued and prepared for publication.

Mr. F. J. M. Stratton, Fellow of Gonville and Caius College, has been appointed Assistant in Astrophysics. He has undertaken together with Mr. Hinks the preparation for publication of Mr. Cookson's completed observations on the variation of latitude and the constant of aberration.

The new astrophysical buildings, consisting of a dome for the Huggins instruments and computing rooms for the astrophysical department, were begun in April, and are just completed. The dome has been supplied by Messrs. T. Cooke & Sons. In August, the Huggins instruments were dismounted at Tulse Hill, with the kind assistance of Sir Howard Grubb, who originally made and mounted the instruments. They were at once moved to Cambridge, and the heavier work of remounting was successfully accomplished in September.

Dunsink Observatory.
(*Director, Prof. E. T. Whittaker, Royal Astronomer of Ireland.*)

The staff consists, as at the close of the previous year, of the Director and Mr. C. Martin, assistant; the instruments in regular use are the Pistor and Martins meridian circle and the Roberts photographic reflector.

The time-service to Dublin has been continued as in previous years.

Two hundred and twenty-six plates have been taken during the year with the Roberts reflector, chiefly in connection with the study of variable stars whose variability is more or less irregular, and which, being circumpolar, may be observed continuously.

A new dome-shutter has been provided for the South Equatorial, and a photographic lens for attachment to this instrument is now being constructed.

The professorial courses of post-graduate lectures by the Director and the demonstrations in practical astronomy by the Assistant Astronomer have been given as in previous years, and the South Equatorial has been employed on the first Saturday in each month in showing objects of interest to visitors.

Durham Observatory. (*Director, Professor R. A. Sampson.*)

The work of the observatory has been devoted to completing the tables of Jupiter's satellites. The computations have been made by Mr. F. C. H. Carpenter and Mr. W. F. Doak. The

tables are now being printed, and should be ready for distribution in about three months.

Observational work has been confined to routine.

Mr. Carpenter was absent on leave from July to November, and his place was taken by Mr. P. F. Everitt. The interval was chiefly devoted to forming a catalogue of the library.

Glasgow Observatory. (*Director, Professor L. Becker.*)

The work with the spectrograph was continued during the year on stars and planets. In September and October five photographs of the spectra of Mars and Moon were obtained on curved films, showing excellent definition from *a* to *H*. No perceptible difference in the intensity of the oxygen and water-vapour bands can be detected.

Funds are as yet not available for the erection of the observing station mentioned in last year's report.

The time service and the meteorological observations have been carried on as in former years.

Liverpool Observatory. (*Director, Mr. W. E. Plummer.*)

No alteration has to be reported in the work of the observatory during the past year. The transit instrument has been kept steadily at work, and the number of observations has been fairly well maintained. These possess little interest from an astronomical point of view, as the results have been used merely to ensure the accuracy of the distribution of time signals and for testing the performance of chronometers deposited for rating. The Equatorial has been employed, as in former years, for the observation of comets, and is now being used for determining the place of Halley's. Some well-known binaries are also kept under observation, with the view of maintaining uniformity of instrument and observer.

The registration of unfelt Earth tremors by the Milne Seismometer and the meteorological work, together with other matters of routine, proceed as usual. In connection with earthquake registration, it may be mentioned that, owing to the kindness of Professor Milne and the generosity of the Committee of the British Association, this observatory has been furnished with a second registering apparatus, which has been placed in an azimuth 90° different from the former. The form of construction adopted is more sensitive than in the older instrument, and for the present it is being used in determining the amount of deformation of the Earth's surface due to the motion of the tides. The flexure is very distinctly shown by these observations, and, under certain conditions, the effect of such a load may be perceptible in nadir observations or determinations of latitude.

Radcliffe Observatory, Oxford.
(*Director, Dr. A. A. Rambaut, Radcliffe Observer.*)

The 24-inch photographic equatorial has been in constant use throughout the year whenever the weather permitted. Towards the end of December 1908 a change was made in the arrangements of the cells of the objective. As originally constructed, the cells required to be separated by a distance of about half an inch for the correction of spherical aberration, and although this space was covered with a close-fitting brass strip lined with leather, it proved to be not quite air-tight, and a great deal of trouble was experienced from time to time in consequence of moisture penetrating to the space between the lenses. To obviate this an iron ring was constructed which exactly filled up the space, and this being bolted firmly between the cells made the whole practically air-tight. This alteration necessitated a readjustment of the crown and flint, which could only be done by trial, and a good many experimental photographs had to be made in the early part of the year before this adjustment was satisfactorily accomplished.

After some experiments as to the length of exposure necessary with this instrument to ensure images of stars of the 14th magnitude, regular observations were commenced in connection with the plan, referred to in a former report, for determining the proper motions of the fainter stars down to that limit of magnitude. The working catalogue contains 136 regions between the limits of $+90^\circ$ and -1° in declination, given by Professor Kapteyn in his *Plan of Selected Areas*. A tracing of the field of the finder is made in each case from Argelander's maps to facilitate identification, and a description of the field in the 18-inch guiding telescope is added to ensure that after an interval of ten years (when the plates will be exposed again) no mistake shall occur about the guiding star selected.

The observation consists in making two exposures, each of 30 minutes' duration, the guiding star being set at two opposite corners of a small square (about 24″ on the side) formed by the wire reticule in the eyepiece. The plate is then stored away in an air-tight box to be kept until 10 years have elapsed.

In addition to the plates so exposed in accordance with Professor Kapteyn's plan, a second series of photographs of the same regions are taken, and are developed in the usual way as soon afterwards as possible, which, by comparison with similar photographs taken at any subsequent epoch, will enable the proper motions to be determined. The storing away of the plates for such a long period (liable as they are to deterioration in the interval) is, according to some astronomers whose opinion cannot be lightly set aside, a very risky expedient. But if these prophets should prove to be right, and these plates be found at the end of ten years unsuitable for measurement, the second series of plates will afford us the means of determining the proper motions, either by comparison in a

stereo-comparator or by measurement of each separately in the usual manner. Thirty-nine such plates have been obtained between May 5 and November 10.

On November 5 this telescope was first directed to Halley's Comet, which was found without much difficulty in the 18-inch, at a time when it was quite invisible in the 10-inch Barclay telescope. From that date to the end of the year nine photographs of this object have been obtained, viz. on November 7, 10, 17, 18, 22, 23, December 4, 18, and 31. All the plates taken in November have been measured, and the apparent places of the comet deduced by comparison with stars of the Bordeaux astrographic catalogue. The reduction of the December plates and of those subsequently taken is in progress, and the results will shortly appear. Two photographs of Daniel's Comet (1909 *e*) have also been obtained on December 18 and 31, but have not yet been measured.

Apart from its use as a guider to the 24-inch photographic equatorial, the 18-inch has been employed occasionally for various observations as a visual telescopic. The Barclay 10-inch has been used for miscellaneous observations, including the observations of variable stars voluntarily undertaken by Mr. Barrett in his leisure time. The stars RW and ST Draconis have been observed by him on eleven nights during the year.

At the date of the last report the measures of the relative parallaxes of the stars in the region surrounding Σ443 (= Ll. 6888 and 9) were in progress. These were completed early in the year and the reduction soon afterwards effected. The results obtained have been described in a paper read before the British Association at Winnipeg, of which a notice appeared in *Engineering* for 1909 September 17. From this investigation the parallax of the double star Σ443, with reference to 190 comparison stars of magnitudes ranging from 8·1 to 11·5, is found to be $+0''\cdot10 \pm 0''\cdot02$. This result is deduced from a single plate with 12 images impressed upon it according to Professor Kapteyn's method, and measured in two positions differing by 180° in orientation.

Although it would be more satisfactory to have had another plate with which to make a comparison, yet the small probable error obtained shows that the result is deserving of considerable weight, and for the relative parallaxes of the 190 comparison stars the probable error denoted by Professor Kapteyn as ρ'_3 comes out only $\pm 0''\cdot018$.

Herr von Zeipel (*Ast. Nach.* 4188) has deduced the parallax of the same star (Σ443) relatively to 50 stars of the 9th magnitude in its neighbourhood, from two plates taken at the Poulkova Observatory, supplied by Herr Kostinsky, and finds $\pi = +0''\cdot057 \pm 0''\cdot017$. The Oxford result, though rather larger than this, agrees closely with it when allowance is made for the fact that the bulk of the comparison stars are so much fainter in the case of the Oxford plate than those used by Herr von Zeipel, only about 12 stars in the former case being as bright as 9·5 magnitude.

In the computing department a great deal of time has had again to be devoted to the reduction of meteorological observations. Amongst other requests for information with regard to the old Radcliffe observations, one from M. F. Kromm of the Bordeaux University Observatory has entailed the re-examination of all the original notes and reductions of the observations of 24 Tauri and η Tauri, made at this observatory during the years 1854 to 1861 inclusive. The parallax computations and the reduction of the plates of Halley's Comet have already been referred to.

University Observatory, Oxford.
(Director, Professor H. H. Turner.)

Volumes v. and vi. of the *Oxford Astrographic Catalogue* are now ready for distribution. Volume vii. (centres $+25^{\circ}{\cdot}0$) will complete the Oxford portion of the catalogue, though it is intended to discuss various matters in an additional volume viii.

It is not proposed to attempt the long-exposure plates for the chart, as the money for reproduction could not be found. But the Astronomer Royal has kindly undertaken to secure these plates at Greenwich; and M. Baillaud, the Director of the Paris Observatory, has very generously offered to reproduce them.

The determination of considerable P.Ms. of faint stars has been continued. No new plates are being taken with this special object; but when a plate taken in the early years and found deficient in stars has been repeated (in the course of revising for press) after an interval of ten years at least, the two sets of measures have been compared. At the time of the last report, results from ten plates in zone $+28^{\circ}$ were available, and of the 2822 stars examined only 10 P.Ms. exceeded $15''$ per century (*M.N.*, lxix. p. 58). Similar results for 30 plates in zone $+26^{\circ}$ were given in April (*M.N.*, lxix. p. 491), and out of the whole 10,000 stars examined only 68 have P.Ms. exceeding $15''$ per century. It appears that these stars with considerable P.M. are scattered almost uniformly over the sky and do not condense in the Milky Way. The work is being continued for zone $+27^{\circ}$, in which 29 plates are available; and some interesting results have been obtained by attempting to assign the P.Ms. to one or other of the apices A and B found by Kapteyn and Eddington; *e.g.* the provisional position found for apex A is about $7^{h}\ 40^{m}\ +10^{\circ}$ instead of $6^{h}\ 0^{m}\ -10^{\circ}$, the discordance being so clearly marked that it can scarcely be accidental. More material will no doubt throw more light on the matter.

In the Computing Bureau of the International Union for Solar Research the position of the Sun's axis in 1860–1870 was investigated from the measures of C. H. F. Peters (*M.N.*, lxix. p. 487), and some work has been done towards tabulating approximate areas for the spots he measured from his original pencil-drawings, kindly lent for the purpose.

During the summer, Mr. E. D. C. Stokes of Glasgow University and Mr. A. H. Joy, Director of the Beirut Observatory, spent some time in Oxford working at the observatory.

The Director attended the meeting of the Permanent Committee for the Astrographic Chart held in Paris in April last.

Temple Observatory, Rugby.
(Director, Mr. G. M. Seabroke.)

There has been a large attendance of members of the school during the past year, and therefore there has been little time for other work. A few double stars have been measured, and the reflector has been used by boys for photographing the Moon. Mr. Hewlett has succeeded Mr. Hawkesworth in residing at the observatory cottage.

Royal College of Science, South Kensington.
(Assistant Professor A. Fowler.)

The comparatively small telescopes available for astronomical work have been chiefly devoted to observations of the spectra of sun-spots and eruptive prominences, in continuation of former records, and to the instruction of students. The spectra of both spots and prominences, so far as could be ascertained with the instruments employed, were identical with those observed in previous years.

Experimental work in relation to solar and other celestial spectra has been continued. The investigation of the magnesium hydride spectrum in the region 5622 to 4372 has been completed (*Phil. Trans.* 209 A, 447); and a further comparison has shown that numerous bands in the red end of the spectra of the third type stars, as well as those in the more refrangible parts of the spectrum previously investigated, are accounted for by titanium oxide (*M.N.*, lxix. 508). The peculiar bands which were recorded in the spectra of Daniel's and Morehouse's Comets have also been identified (*M.N.*, lxx. 176). Other investigations related to the spectrum of vanadium (*Ap. J.*, xxx. 127), and to the spectra of barium and strontium hydrides (*Ap. J.*, xxx. 231).

Solar Physics Observatory, South Kensington.
(Director, Sir Norman Lockyer, K.C.B.)

Observations of Sun-spot Spectra.—The Sun was visible on 232 working days during 1909, and observations of sun-spot spectra were made on 75 days, 138 spots being examined in the F—D region. The chief widened lines are still those due to Vana-

dium, Titanium, Magnesium associated with Hydrogen, and Scandium.

Further experiments with the long-focus Sun-spot Spectrograph have been attempted, and abandoned until another site for the observatory can be occupied.

Spectroheliograph.—Attempts to secure photographs of the Sun in "K" light with this instrument were made on 147 days: 286 negatives, showing the distribution of calcium flocculi, were taken, and 231 of them have been selected for measurement and reduction. In addition to these, 57 "limb" negatives were obtained, thus securing a record of the prominences; on most of these an exposure was made on the disc as well.

In accordance with the arrangement made with the Indian Government, 370 spectroheliograms, showing the disc in "H" or "K" light, have been received from the Kodaikánal Observatory during 1909; these cover the period July 1, 1908 to August 31, 1909. Fifty-three glass positives of the Sun's limb in "K" light were forwarded from South Kensington to Kodaikánal during the year.

The work of measuring and reducing the areas of the calcium flocculi on the disc has proceeded regularly, and the whole of the Kodaikánal negatives for 1906 have been measured and reduced; those for 1907 have been commenced. Independent measures of the areas shown on the South Kensington and Kodaikánal negatives for July 1906 indicate that the results from the two sets of plates are comparable. It was therefore decided to proceed with the measurement of the South Kensington negatives for those days on which no photograph was secured at Kodaikánal, and this part of the work for 1906 is now nearly finished.

To complete the record further, Professor Hale has been asked to supply photographs for the recent dates. Whilst unable to do this owing to pressure of work, he has kindly arranged to forward measures of the Mount Wilson photographs, and it is hoped that these may be incorporated with the Kodaikánal and South Kensington measures. The Mount Wilson measures are not in quite the same form as the others, but doubtless a method of making them uniform will readily be found when Professor Hale forwards, for comparison, the measures for days already reduced in the South Kensington and Indian records.

Sun Photographs.—Daily photographs (glass negatives) of the Sun's disc, taken with the photoheliograph, have, as usual, been received from Dehra Dûn and Mauritius, the gaps in the Indian record being filled up, so far as possible, by negatives from Mauritius and Greenwich. The negatives are forwarded to Greenwich for measurement and reduction as they are required. Positives on paper are also received from Dehra Dûn, and these are mounted on cartridge paper and bound up into half-yearly volumes. Since the beginning of 1906 enlargements of spectroheliograms, when possible, have been mounted alongside the paper prints for comparison and ready reference.

Night Work.—The remarks made in previous years concerning the atmospheric conditions at South Kensington are still applicable, and really clear night skies are extremely rare. Work with the 36-inch reflector was seriously hampered during the first part of the year because the mirrors badly required resilvering. Owing to lack of funds, this work could not be completed before September 22, but since then photographs of Halley's Comet have been secured on several fairly clear nights. A few attempts to photograph Daniel's Comet (1909 *e*) and the spectra of various nebulæ have been rendered nugatory by clouds.

With the 6-inch Henry prismatic-camera with two 45° prisms 71 photographs of 16 stellar spectra were taken, and a series of plate-tests for the purpose of determining the best plates to employ for the green region was made. The results of these tests indicate that it may be possible to extend towards the less refrangible portion of the spectrum the region of stellar spectra hitherto discussed at this observatory.

The 2-inch calcite-quartz spectrograph was regularly employed for photographing the spectra of pairs of stars under identical conditions so far as possible, in order to test their relative extensions into the ultra-violet; criteria as to the relative apparent temperatures of the stars are thus obtained; fifteen pairs of stars were examined during 1909. The 6-inch Dallmeyer camera, to which the calcite prismatic camera is attached, was used on several occasions for photographing the region of Halley's Comet, but the lack of a suitably large finder renders the photography of such faint objects very difficult.

The 9-inch prismatic camera was occasionally employed, and, among others, several spectrograms of Mira Ceti were obtained during the September maximum of that star.

Publications.—Papers dealing with Australian Meteorology, the Magnetic Storm of September 25, 1909, the Origin of Certain Hitherto-unknown Lines in the Spectrum of ϵ Orionis, and the Investigation of Solar and Stellar Alignments in British Stone Monuments, have been published during the year. Other papers, dealing with the Spectra of the Sun and the Lower-type Stars with reference to Sun-spots, the Origin of Certain Unknown Lines in Stellar Spectra, the Distribution of the Mean Winter Pressure Amplitudes in the Southern Hemisphere and Southern Hemisphere Air Circulation, the Spectrum of ϵ Ursæ Majoris, etc., etc., are nearly ready for publication.

Stonyhurst College Observatory. (*Director, Rev. W. Sidgreaves.*)

The solar spots have been observed as usual, and 193 drawings have been made. On five days the surface was found free from spots.

With the solar grating spectrograph a series of photographs of the spectra of the larger sun-spots has been obtained in the regions

of the red and yellow, and these have been supplemented by eye observations taken with the 12-prism spectroscope attached to the 15-inch equatorial.

The stellar spectrograph has been employed, with Messrs. Wratten & Wainwright's panchromatic plates, on the brighter stars for the spectra of the red region; but progress has been very slow; and the red dispersion of the single compound prism has been found to be hardly enough to bring out the fine lines of this part of the spectrum. At present, trials are being made with the greater dispersion of the two prisms belonging to the instrument.

A Milne seismograph of non-magnetic material has been mounted in the underground magnetic chamber. Its continuous photographic record, beginning with July 1, has shown an average of five well-defined earthquakes per month; besides a great number of smaller disturbances, which are registered and sent to Dr. Milne for comparisons with those registered at the Liverpool, Edinburgh, and Paisley observatories.

Wolsingham Observatory (Rev. T. E. Espin's).

The micrometrical measures of neglected double stars and the search for new pairs has been continued in the past year, and the results presented to the Society.

Mr. Franklin-Adams' Astrographic Laboratory.

From January to the end of November 1909 all work that could be stopped or postponed had to give way to a thorough overhaul of the thousands of plates photographed during the past fifteen years for the chart and index, negatives, positives, and reinforced negatives, now all complete. The result of the re-examination is that the northern plates have, from many years' experience, so much improved upon the standard of the southern plates taken in the Cape during 1903–4 that it has been decided to repeat the entire southern series. Mr. Franklin-Adams had taken berths by the steamer of November 6 to go out and do this work, but illness spoiled the plan, and Mr. R. J. Mitchell, his assistant, sailed on December 18 to take his place.

In the meantime, elaborate investigation is being made as to possibility of reproducing upon paper the faint stars. Many of the plates include each about a million stars, down to mag. 14·8 or 14·9, by Kapteyn's formula (*Gron. Publ.* 18). More than half of these are lost if the printing only reaches magnitude 14·0; everything is being tried—photogravure, platinum, carbon, velox, and most of the British bromides.

Enumeration and classification of sample degrees from each of the northern plates will be begun as soon as an assistant with experience of astrographic chart work can be found to help for a few months.

Sir William Huggins' Observatory, Upper Tulse Hill.

During the past year the telescopes and other astronomical instruments of this observatory have been transferred to a new observatory at Cambridge specially erected to receive them, which is in connection with the University Observatory, and is under the direction of Professor Newall, F.R.S.

The Physical Laboratories remain in full work, and researches in connection with the interpretation of stellar spectra are in progress.

Mr. Maw's Observatory, Outwood, Surrey.

The chief work done at this observatory consists of measures of double stars, with some planetary and lunar observations. The weather conditions during the past year have been very unfavourable, and the number of measures made has been much below the average.

Mr. Newbegin's Observatory, Sutton, Surrey.

Fifty-eight observations on prominences were made during the year, resulting in a total of 374, or daily average of 6·4. The prominences mainly occupy the region between 50° N. and 50° S. latitude, there being but very few beyond those points. Spots have been numerous, and many very active, especially that of September 24, when C, D, D_3, and small *b* group were intensely bright: on the day following this observation occurred the great magnetic storm.

Photographs were constantly taken of the solar image, and spectroscopic details of the spots recorded.

Mars also was carefully sketched on many nights, many of the details being compared with those of Mr. Phillips, Ashtead, and on two occasions combined with his.

Rousdon Observatory, Devon.
(Sir Wilfrid Peek's; C. Grover, Observer, in charge.)

The building is in good repair, and the astronomical instruments are in perfect working order. Weather generally has been favourable, particularly during the latter half of the year. August was the best month, with 22 fine nights, and the total number of nights' observation during the year was one hundred and forty-three. Observations of long-period variable stars were continued, and 368 magnitude determinations were recorded, making a total of 10,888

magnitudes during the twenty-four years this work has been in progress. Argelander's method is followed: each observation consists of the mean of five visual comparisons of the variable with five other stars whose magnitudes have been carefully determined, and all comparisons are made with stars in the same telescopic field as the variable. In nearly all these observations the tables of comparison stars, with their photometric magnitudes, as furnished by the Harvard College Observatory, have been used.

The instrument in use throughout has been the 6·4-inch equatorially-mounted Merz refractor, the powers mostly used being 34, 80, and 132. A 13th-magnitude star is about the limit of vision with this telescope.

During September and October the planet Mars was observed on nearly every fine night, and 14 drawings were made under favourable conditions. Many of the well-known features were very distinctly seen.

Halley's Comet was first seen November 18, when it was excessively faint, and about the minimum visible with this telescope. By the end of the month it was slightly brighter, but during the whole of December there was very little change, and on December 31 it was extremely faint, and only just visible as a very feeble diffuse nebulosity.

Observations with the transit instruments have been regularly taken for the regulation of the sidereal clock.

Rev. T. E. R. Phillips's Observatory, Ashtead, Surrey.

The 12¼-inch Calver Equatorial has been used chiefly for the study of Jupiter and Mars and the measurement of double stars.

In addition to the usual drawings and transit observations of spots over the central meridian of Jupiter's illuminated disc and their reduction, a considerable number of micrometer measures of the belts were made for latitude.

Mars was observed systematically from the early part of August to the beginning of December, but, owing to the comparatively low altitude of the planet and atmospheric troubles, conditions were rarely satisfactory.

The star measures were partly those of Struve pairs and partly of a number of faint and neglected pairs in Sir John Herschel's list.

Halley's Comet was first seen on November 16, and was subsequently observed and estimates made of its brightness on every available opportunity.

The Dollond transit instrument lent by the B.A.A. was used for time determination, and meteorological observations were made regularly throughout the year.

Mr. Saunder's Observatory, Crowthorne, Berks.

The principal work has been upon the Moon. A catalogue of nearly 3000 measured positions has been prepared, and will, it is hoped, shortly be ready for publication.

Khedivial Observatory, Helwân, Egypt.
(Superintendent, Mr. B. F. E. Keeling.)

A considerable number of improvements have been made to the Reynolds 30-inch reflector. During the year, Mr. Knox Shaw made 82 exposures on nebulæ. Photographs of Halley's Comet were obtained on August 24, September 13, 15, and 16, October 15 and 22, and December 7.

A Riefler clock has been purchased, and some improvements have been effected in the time service.

The usual meteorological, seismological, and magnetic observations have been made.

Kodaikánal and Madras Observatories.
(C. Michie Smith, Director.)

The year was a favourable one for solar observations, as there were only 14 days on which no observations were possible, though there were many days on which thin clouds, especially cirrus, prevented spectroscopic observations of the higher class being attempted.

Photoheliograms were taken on 332 days, and, with one exception, all the negatives required to complete the Greenwich—Dehra Dûn series were sent to the Astronomer Royal.

Sun-spots.—Observations of sun-spots were made on 349 days, and their positions were roughly determined by projection. The number of new groups observed was 221, with a mean daily number of 3·5, against 262 and 3·9 in 1908. The solar activity, which had fallen rather low in the middle of the year, increased greatly during the last three months, when the spots were both numerous and large. Southern groups were again far more numerous than northern groups. There were four days on which the Sun was free from spots at the time of observation.

Spectroscopic Observations.—Prominences were observed and drawn on 309 days, and the drawings were compared with photographs taken with the spectroheliograph. The spectra of eruptive prominences were observed as far as time permitted. During the greater part of the year prominences were numerous, and several large and interesting ones were observed and photographed at short intervals while rapid changes were taking place in them. Sun-spot spectra were studied on all favourable occasions.

The $3\frac{1}{4}$-inch grating spectrograph was employed early in the

year in photographing spot spectra with high dispersion, for the purpose of detecting relative displacements of the lines which are most and least affected by pressure. All the best plates of this series have been measured, and the results have been published in the first part of the *Kodaikánal Memoirs.*

A new and very powerful spectrograph has been constructed during the year, in which a 6-inch plane grating by Michelson is employed, and an 18-inch silver on glass parabolic mirror forms the solar image on the slit plate. Work with this instrument has been concentrated on investigations connected with the systematic line-displacements which have been found to be a constant feature in all spot spectra obtained under suitable conditions. A fair proportion of the large number of plates obtained have been measured.

An excellent series of limb and centre comparison plates of selected regions of the spectrum has also been secured with the new spectrograph. These will be used for investigating pressure effects at the Sun's limb.

Spectroheliograph.—Spectroheliograms were taken on 337 days, but on 52 of these the record was either incomplete or unsatisfactory owing to unfavourable weather. A new spectroheliograph for work in the C line was under construction towards the close of the year.

Publications.—Bulletins Nos. xiv. to xviii. were published during the year, and the first part of the *Memoirs* of the Observatory was printed and ready for issue at the end of the year.

Meteorological and seismological observations were continued as in former years.

At Madras, the chief astronomical work continues to be the maintenance of the time service.

Adelaide Observatory, South Australia.
(*G. F. Dodwell, Government Astronomer.*)

The present report covers the period 1907 to 1909 inclusive. Sir Charles Todd retired from active service on December 31, 1906, and was succeeded in the management of the observatory by Mr. R. F. Griffiths, formerly Chief Assistant.

The work of 1907 was mainly meteorological, and included the daily publication of weather reports from all the telegraph stations in the State and selected stations in the rest of Australia, also the daily forecasts, which had a high percentage of success. The volume for 1904 and 1905 was also printed and distributed during the year.

The astronomical work comprised chiefly the observations of clock stars for the time service.

The time-ball at the Semaphore was dropped daily, and the time was also distributed throughout the State in the usual way.

The 8-inch Cooke Equatorial was used for observations of comets

and of the phenomena of Jupiter's satellites, and for educational purposes.

After Sir Charles Todd's retirement, the meetings of the Astronomical Society of South Australia, which were up to this time held at the observatory, were held in the Adelaide Institute Buildings, the latter being a more convenient place of meeting.

On January 1, 1908, the meteorological service was transferred to the Commonwealth; Mr. Griffiths received a high appointment in the Central Meteorological Bureau, and Mr. G. F. Dodwell was appointed to the charge of the meteorological work at Adelaide.

The astronomical service remained under the State control, but an arrangement of a temporary nature was made between the State and Commonwealth Governments whereby the Commonwealth officers at Adelaide were permitted to carry on the time service and other astronomical work.

The arrangement was continued until June 1909.

During this period the daily publication of the weather reports was extended and improved under the direction of the Commonwealth Meteorologist, Mr. H. A. Hunt, and the volumes for 1906 and 1907 were finally prepared for printing.

In June 1909 the arrangement with the Commonwealth Government in regard to the astronomical work was discontinued, and the State Government appointed Mr. G. F. Dodwell as Government Astronomer; Mr. E. Bromley being placed in charge of the meteorological service by the Commonwealth authorities.

In regard to future astronomical work, it is hoped that, with a small but capable and enthusiastic staff, whose time will be devoted wholly to astronomy, useful work will be done.

Besides the daily time service and other miscellaneous work, it is intended particularly to co-operate in the plan of zone observations advocated by Mr. W. E. Cooke, Government Astronomer of Western Australia.

It is thought best to work in the Zone 20° to 30° south, which is contiguous to that now being observed at Perth (30° to 40° south).

Various improvements are being effected to the Transit-Circle Telescope (6-in., Troughton and Simms), the division errors of which will, as a preliminary, be re-determined.

On June 22, the new Milne Seismograph was set going by Sir Charles Todd. The photographic barograph and thermograph have also been installed in the Seismograph house, which was erected in the observatory grounds, to the north-west of the Transit room, towards the end of 1907.

Electric light has been substituted for gas in the Transit room and dome, and the electric light is also used for the Seismograph, and is found to be very successful.

Observations and drawings of Mars were made during the recent opposition.

A monthly lecture on astronomy, delivered to country institutes, has met with appreciation.

The first observation of Halley's Comet made at the Adelaide

Observatory, was on November 24, 1909, the 8-inch Cooke Equatorial refractor being used. Up to the end of the year, moonlight and cloudy weather interfered considerably with observations, but there were 16 nights on which the comet was observed, and 67 measurements of position were made. Unfortunately the observatory does not possess a photographic telescope, so that no photographs could be taken of the comet.

Melbourne Observatory. (*Director, Mr. P. Baracchi.*)

	Observations in R.A.	Observations in N.P.D.
Transit-circle.		
Clock stars	928	236
Azimuth stars	520	304
Reference stars of the Melbourne Astrographic Zones	1124	1106
Miscellaneous stars	112	353
Total	2684	1999
Observations of Collimation		234
,, Level		198
,, Nadir		166
,, Flexure		12

The complete working list of reference stars in connection with the Melbourne Astrographic Zones contained at least 10 stars for each plate. The whole of these, with the exception of about 70, have now been observed in both co-ordinates not less than three times.

The miscellaneous stars comprise, chiefly, part of a list of 100 stars selected from Newcomb's Fundamental Catalogue for an investigation of refraction, now in course, and some comparison stars used in observations of Halley's Comet.

All meridian observations have been fully reduced. The Annual Star Catalogue for 1908 has been completed, and the separate results and catalogue for 1909 are now being prepared.

Astrographic Equatorial.—Plates taken during the year.

Catalogue plates, Series I.	22
Do. Series II.	5
Chart plates with single exposure of 60^m	22
Do. with triple exposure of (30^m, 30^m, 30^m)	31
Plates of special objects (comets, etc.)	68
Oxford chart regions	10
Pole plates	27
Plates for adjustment	26
Rejected plates	31
Total	242

About 400 Chart plates with triple exposure still remain to be taken. The second series of Catalogue plates is proceeding, in conformity with the recommendations of the last Paris Conference.

Measurement of Plates.—Plates measured in 1909 :

Sydney Zones, 216 plates containing 109,645 stars.
Melbourne Zones, 18 plates containing 234 stars.

The present state of this work is as follows :—

Plates completely measured :

Sydney Zones, 921 plates containing 537,851 stars.
Melbourne Zones, 1226 plates containing 375,061 stars.

494 Sydney regions still remain to be measured.

The measurement of plates of the Melbourne Zones is practically completed.

The Astrographic Equatorial was employed on 46 nights in January, March, and April in photographing Comet Morehouse and, later in the year, in taking plates of the regions of Halley's Comet. Three plates taken on two nights gave the position of this comet satisfactorily.

A series of positions of Comet Morehouse was obtained with the 8-inch Equatorial on 32 nights from February to April, and observations of Halley's Comet were made with the same instrument on 6 nights in December.

All the various routine duties for local public requirements, as specified in reports of previous years, were carried out as usual.

Perth Observatory, Western Australia.
(*Director, Mr. W. Ernest Cooke.*)

Meridian Observations.—The observations of the *Étoiles de repère* for the Zone 31°–3° were completed during the year, and the catalogue of these stars (2047) is now ready for the printer. This will form vol. iv. of Perth Meridian Observations, the former volumes embracing the Zones 33°–5° (printed and distributed during the year) and 39°–41°, and the "intermediate" stars for the whole region 31°–41°. Next year the Zone 35°–7° will be observed, completely if possible.

Astrographic Catalogue.—All the photographs have now been taken, but occasional regions are re-observed whenever the measures reveal serious blemishes of any description. Nearly all the plates with centres at 32° have been measured in two positions, and the manuscript prepared for the printer. Computations of plate constants are now in progress, using as reference stars the *Étoiles de repère* of vol. iv., already mentioned. An effort will be made to publish the first volume of the Astrographic Catalogue during next year.

Paris Conference.—The Government astronomer attended the Paris Conference as representative of Western Australia.

Miscellaneous.—The time service has been maintained as usual. The time-ball at Fremantle was dropped daily at 1 p.m., with the exception of a few occasions when faults occurred on the line.

Owing to the great demand for evening admission, it has been found necessary to increase the number of visitors' evenings to five per month, and frequently more.

The following is a résumé of the work done during the year:—

	Plates completely measured in direct and reversed positions	151
	Number of stars measured	55,796
	Plates rejected and retaken	45
	Nights on which time was determined	180
	Observations of clock stars in R.A.	778
From Jan. 4 to June 8.	,, zone ,, ,,	2683
	,, ,, ,, N.P.D.	2739
Separate determinations of Collimation error		7
,, ,,	Level error	109
,, ,,	Azimuth error	99
,, ,,	Nadir point	72

Lovedale Observatory, South Africa.
(*Dr. A. W. Roberts.*)

During the year over 2000 observations of variable stars were made, chiefly of Long Period stars.

For the year, the observations of Short Period and Algol stars were stopped. They will, however, be begun again in 1910.

The year had an exceptional number of cloudy nights, which hindered observations considerably.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Minor Planets.

The following 70 planets have been discovered during 1909.

Letter and Number.	Date.	Discoverer.	Letter and Number.	Date.	Discoverer.	Letter and Number.	Date.	Discoverer
FL ...	Jan. 9	K	GL ..	Feb. 25	K	HJ ...	Sept. 12	P
FM ...	9	K	GM ...	Mar. 9	W	HK ...	16	W
FN ..	16	M_2	GN ...	14	W	HL ...	16	L
FO ...	18	W	GO ...	Apr. 8	K	HM ...	21	K
FP ...	18	K	GP ...	9	W	HN ...	21	K
FQ ...	18	K	GQ ...	9	K	HO ...	Oct. 10	K
FR ...	18	K	GR ...	11	K	HP ...	15	H
FS ...	22	K	GS ...	11	K	HQ ...	15	H
FT ...	24	K	GT ...	15	W	HR ...	5	D
FU ...	26	K	GU ...	19	K	HS ...	5	D
FV ...	26	K	GV ...	19	K	HT ...	5	D
FW ...	28	K	GW ...	22	K	HU ...	17	H
FX ...	28	K	GX ...	22	K	HV ...	17	H
FY ...	28	K	GY ...	May 11	K	HW ...	18	H
FZ ...	28	W	GZ ...	13	K	HX ...	Nov. 6	H
GB ...	28	W	HA ...	June 17	K	HY ...	9	W
GC ...	18	K	HB ...	Apr. 7	M_2	HZ ...	Oct. 16	M_1
GD ...	Feb. 18	W	HC ...	July 23	W	JA ...	Nov. 9	H
GE ...	18	W	HD ...	Aug. 8	K	JB ...	7	M_1
GF ...	18	K	HE ...	12	L	JD ...	Oct. 19	B
GG ...	19	K	HF ...	15	K	JE ...	Dec. 14	L
GH ...	20	K	HG ...	16	P	JF ...	16	H
GJ ...	21	K	HH ...	25	P	JG ...	11	M_1
GK ...	21	K						

The initials stand for: B = M. Boinot, Paris; D = Mr Davidson, Greenwich; H = Herr Helffrich, Heidelberg; K = Herr Kopff, Heidelberg; L = Herr Lorenz, Heidelberg; M_1 = Dr. Metcalf, Taunton, Mass.; M_2 = Mr. Melotte, Greenwich; P = Dr. Palisa, Vienna; W = Professor Wolf, Heidelberg.

An object named GA proved to be the seventh satellite of Jupiter, one named JC proved to be 50 Virginia, the ephemeris being 6° in error, a large amount for one of the older planets.

The following planets have received permanent numbers: AG 645, BF 655, CC 660, CL 661, CW 662, DG 663, DH 664, DK 665, DM 666, DN 667, DO 668, DQ 669, DR 670, DV 671, DY 672, EA 673, EP 674.

The planets previously numbered 645, 655, subsequently proved to be identical with 398 Admete, 49 Pales; 665 is identical with SJ discovered in 1906.

BE = 414 Liriope, CM = 616, DL = 421 Zähringia, DP = 635, EE = 595, XZ (discovered 1907) = 469 Argentina. Elliptical elements have been calculated for DC, DW, but they are too uncertain for permanent numeration. FK, FY will probably receive permanent numbers when all their observations have been published. Other planets up to FZ do not receive permanent numbers.

One of the planets FL or FM may be 209 Dido. The following planets have received names: 576 Emanuela, 589 Croatia, 662 Newtonia, 674 Rachele.

The following planets (*inter alia*) were re-observed during the year: QX (discovered in 1905) on April 10, 11; 624 Hector on April 15; 659 in the spring; 433 Eros at Greenwich during the summer (this planet will be in opposition in May in S. Decl. 47°).

A. C. D. C.

The Comets of 1909.

Cometary discoveries and observations during the past year include the following.

Comet *a* 1909. A faint object discovered by M. Borrelly of Marseilles on June 14, and independently by Mr. Daniel of Princeton, N.J., on the following night. The comet had passed the perihelion passage some ten days earlier and was rapidly growing fainter. The circumpolar position of the comet favoured observations, but it was not followed beyond the end of July. The orbit is probably parabolic.

Comet *b* 1909, a return of Perrine's Comet, 1896 VII., was photographed at Heidelberg on August 12, the approximate position having been determined by Dr. Ristenpart. In the period from 1896 to 1903 the perturbations by Jupiter were considerable, and these were carefully computed by the same astronomer. But unfortunately, owing to the intrinsic feebleness of the comet and the proximity to the Sun, it passed through perihelion without being observed. As originally the comet had been observed for a period of less than three months, the mean motion was somewhat uncertain, and by the double revolution the insecurity of this element was increased. Under these adverse circumstances, to predict the time of perihelion passage with an error of less than four days was a

very successful result—upon which Dr. Ristenpart may be congratulated. Theoretically, this comet should have increased in brilliancy slowly till the end of November, but it has afforded an example of irregular variation in lustre. Early in September Dr. Max Wolf reported that the comet was easily visible, but on October 11 it was seen with difficulty, and on November 6 was invisible. On November 9 photographic search failed to find it. The comet was, however, re-observed on November 20.

Comet *c* 1909. A return of Halley's Comet, first definitely recognised and announced by Dr. Max Wolf on September 11, though the image was suspected on a plate taken on August 28. This suspicion has since been confirmed. On examination, subsequent to the announcement of the discovery, it has been proved that the comet was photographed at Greenwich on September 9, and at Helwân as early as August 24. While these results are eminently satisfactory, the credit of the discovery naturally remains with Dr. Max Wolf, who, by his early announcement, made the observation of the comet possible elsewhere. At Mount Hamilton the comet was photographed on September 12, but does not appear to have been observed visually in the 36-inch refractor till October 16. Early observations were secured at Yerkes. In November the comet became visible in telescopes of moderate size, but in this case, again, the increase in brilliancy has not been steady and uniform.

Dating from the Helwân observation, the comet became visible some 239 days before perihelion passage, which, it may be assumed, will occur on April 19·7 G.M.T., or about three days later than the date assigned by Messrs. Cowell and Crommelin, necessitating at the time of discovery, a correction to the ephemeris of only $+24^s$ in R.A. and $-4'$ in declination. Considering the influences exercised by Jupiter on the orbit during the period 1835–1910, a period in which the perturbations were nearly at a maximum, the accuracy of the prediction bears eloquent testimony to the care which must have been exercised in their computation. It is difficult to express adequately the accuracy attained by Messrs. Cowell and Crommelin in this research; but since the date of perihelion passage depends upon the mean motion, and this again upon the mean distance, it may be pointed out that the correction needed to the semi-major axis of the ellipse is only about 130,000 miles, a quantity of quite the same order of magnitude as the uncertainty of the Earth's distance from the Sun. The success of their achievement is deserving of the warmest recognition, and has been universally acknowledged.

Spectroscopic observations began early. On October 22, after two hours' exposure, a faint spectrum was photographed at the Lick Observatory. From that date the physical observations have been continued with greater success as the comet increased in brightness. It is reported that American astronomers have appointed a committee to ensure the continuity of the observations on a systematic plan.

Comet *d* 1909. A return of Winnecke's Comet, which, like Perrine's, had passed its last return without being observed. This comet has been very insufficiently observed since 1892, and the elements were becoming somewhat uncertain. This uncertainty was aggravated in the last revolution by the comet's close approach to Jupiter, the minimum distance being 0·41 R in December 1906, while for a year and a quarter the distance between Jupiter and the comet was less than the Earth's distance from the Sun. The perturbations of the mean anomaly amounted to nearly 7°, and the other elements were much altered. In presence of these unfavourable circumstances, an error of only seven hours in the computed time of perihelion passage is remarkable, and furnishes a sufficient proof of the care bestowed by Dr. Hillebrand on the calculation. The comet was found on October 31 by Dr. Porro of the La Plata Observatory. The great southern declination renders observation impossible in the northern hemisphere; and as at the time of discovery the brilliancy was diminishing, it is to be feared that few observations have been secured.

Comet *e* 1909. A fairly bright comet found by Mr. Daniel of Princeton, New Jersey, on December 6; but the brilliancy has faded rapidly since. It is now shown to be one of Jupiter's family, with a period of about 6 years.

The orbits of the following comets have been definitely determined during the year:—

Comet.	Character of Orbit.	Calculator.	Reference.
1811 II.	Ellipse	A. Nekrassow	*Ast. Nach.* 4349
1886 III.	Hyperbola	Kobold	,, ,, 4347
1898 VI.	Parabola	Curtis and Richardson	,, ,, 4365

The elements of this last comet resemble those of 1785 I., with the exception of the perihelion distance. W. E. P.

The Secular Motions of the Elements of the Inner Planets.

In chapter vi. of his *Astronomical Constants* Newcomb has given the differences between theory and observation for the secular changes of the inclinations, eccentricities, nodes, and perihelia of the four planets Mercury, Venus, Earth, and Mars. As the ecliptic is the plane of reference, there are thus 14 residuals to be explained. In 4 of them the residuals are less than the corresponding probable errors, in 2 they are about equal to them, and in 8 they are greater. Of the latter, the outstanding motion of the perihelion of Mercury is large, while in three other cases the residuals are respectively 5, 3, 2 times the probable errors.

In his paper "Das Zodiakallicht und die empirischen Glieder in der Bewegung der innern Planeten" (*Münch. Ber.*, vol. xxxvi. pp. 595–622), Professor H. Seeliger seeks to explain these residuals. He

makes three hypotheses in order to do so. The first consists in the supposed presence of a lens-shaped uniform distribution of matter in the form of an ellipsoid of revolution, in which the equatorial axis is ·24 (the Sun's distance from the Earth being unity) and the polar axis ·024, the latter being somewhere near the Sun's axis of revolution. The second hypothesis is another lens-shaped ellipsoid of matter, uniformly distributed and similarly placed, but with a much smaller density, and axes 1·20, ·24 respectively. The third is a motion of the axes of co-ordinates in the plane of the ecliptic, with the consequent introduction of "gyroscopic" terms due to this motion of the axes of reference.

Five constants are left arbitrary at the outset:—the common inclination and position of the node on the ecliptic of the two ellipsoids, the two densities of the matter composing them, and the angular velocity of the axes in the plane of the ecliptic. To determine these 5 constants, Professor Seeliger has 10 equations of condition formed from the 14 residuals, since he states that the 4 eccentricities are not sensibly affected.

The net result, after the 5 constants have been determined and the secular motions corrected, is as follows:—Instead of 8 residuals greater than their probable errors, there remain 3; we still have 2 residuals equal to their probable errors, and consequently 9 residuals less than their probable errors. Thus, on the whole, the three hypotheses with 5 undetermined constants have been used to explain $8-3=5$ residuals. It is true that of the 10 residuals that Professor Seeliger treats, 7 are diminished to very small dimensions, but 2 are increased and 1 is unchanged; the outstanding errors in the eccentricities, only one of which was less than its probable error, are untouched. The total mass of the matter which results from the suppositions is 3×10^{-7} that of the Sun.

In the chapter previously quoted, Newcomb had considered hypotheses which in their effect do not greatly differ from the ellipsoids of Professor Seeliger, namely, rings of planets between Mercury and the Sun, and between Mercury and Venus, and also the lens-shaped zone of diffused matter supposed to produce the zodiacal light. The suppositions were separately treated, because the introduction of numerous constants which are not otherwise tested is undesirable. He did not seem disposed to admit them, for various reasons. He considered it possible that the matter causing the zodiacal light is responsible for the anomalies in the motion of Mercury and Venus, and that the minor planets between Mars and Jupiter are responsible for those of Mars and the Earth: the latter was long ago suggested by Leverrier. In both cases there are difficulties.

The assumed motion of the co-ordinate axes is more doubtful. The evidence from other sources appears to be rather unfavourable than otherwise (E. Anding, *Enc. math. Wiss.*, Bd. v. 2). Its amount is chiefly determined by Professor Seeliger from the motion of the node of Mercury; and though it will explain a large part of the motion of the node of Venus and also of the perihelion of Mars,

it is responsible for a new discordance in the node of Mars. The smaller and more dense lens of matter, with its three constants, sensibly affects only the perihelion and inclination of Mercury, the inclination of Venus, and, to a small extent, the node of Venus. The large lens of low density sensibly affects only the node of Venus. The various hypotheses appear to require further evidence.

E. W. B.

A supposed Planet beyond Neptune.

The discovery of remote satellites of Jupiter and Saturn has brought again to the front the problem of a planet beyond Neptune. It can hardly be denied that there was an element of good fortune in the successful prediction of the place of Neptune. Both Adams and Leverrier assigned a motion to the planet decidedly different from the truth; there was only a single date when the indicated place was true, and no steps were taken to secure that this should fall at the epoch of the search. It is not likely that this good fortune will be repeated. Hence, it is desirable not to trust to coincidences, but to look closely to the logic of the researches that attempt to assign a position to an unknown planet beyond Neptune. The first calling for notice is Professor G. Forbes's argument from the aphelia of certain comets (*Proc. R.S.E.*, 1880, x.; *Observatory*, 1880, p. 439; *M.N.*, 1908, lxix. p. 152). A list of comets is given to which major axes are ascribed of about 100 units. In his earlier papers Professor Forbes indicates an ecliptic planet of mean distance 100, which would have approximately the same longitude as these comets at their aphelia. But this is not enough; the inclination of the axes of the orbits of these comets to the ecliptic is in no case small, and hence the distances between the bodies at their conjunctions in longitude would be enormous. In his later paper Professor Forbes gives up the theory of a planet in the ecliptic, and we need not refer further to it than to point a warning from a curious coincidence which it showed with the result of an independent and earlier, though unpublished, investigation by Professor D. P. Todd (*Am. J. of Science*, xx., 1880, p. 225), working by a graphical method on lines given in Herschel's *Outlines of Astronomy*, and using as material the unexplained residuals in the position of Uranus. Forbes found for the place of his planet, in 1880, longitude 174°; Todd, in 1878, longitude $170° \pm 10°$, and he spent 30 nights in searching this region, and concluded with confidence that no planet with a disc of 2″ was present.

Of much greater interest is Professor Forbes' inquiry as to the indications of a planet in an orbit of considerable obliquity to the ecliptic. The comet of 1556, of direct motion, was identified by Hind with that of 1264, and accordingly he predicted its return in 1848, but neither then nor since has it come. Now the

three retrograde comets 1843 I., 1880 I., 1882 II., show similarities in their orbits recognisable at a glance, and Forbes shows that there is practically a single common position for their perihelia, which again is the same as that of the comet of 1556, though, of course, this last is subject to a little uncertainty. Forbes assumes that the earlier comet was disrupted into three fragments and its motion reversed at aphelion by encounter with some other body. This is plausible enough, though it involves ascription of periodicity to the three comets in question. Further, it appears that a plane drawn through the aphelion of the three and that of the comet 1861 I. passes within 13′ of the aphelion of comet 1840 IV. This suggests an orbit for the suspected body. The aphelion distances are passably well known, and are taken at 87·5, 110·4, 99·7; their orbit longitudes are 114° 57′, 24° 6′, 196° 6′. Forbes shows that a supposed planet with mean distance 105·1 and eccentricity 0·1665 passing the first point in A.D. 1702, and with its aphelion at that point, would have overtaken the second comet in A.D. 409 and the third in A.D. 821. The suggestion is that these were the occasions of capture of the comets; the second would have made three returns in the interval, and they may be reasonably identified with comets of A.D. 1444, 1032, 617.

The distance of the planet from the comets at conjunction in longitude come to 0·0, 7·7, 0·3, but it must be remembered that the process of fixing the apse and epoch in the planet's orbit are avowedly empirical. The conclusions, if not demonstrative, are certainly striking, for they involve four apparently genuine coincidences. The place of the body in 1910 would be ecliptic long. 216° 8′, lat. − 33° 20′.

Referring to the indications from unexplained perturbations to the known planets, nothing can be found from the residual errors of Neptune. M. Gaillot (*Comptes Rendus*, 1909 March 22), proceeding by known methods, found that the hypothesis of a single exterior planet would only reduce the probable error from ± 1″·02 to ± 0″·94, so that inquiry on these lines may be dismissed.

Herschel's discussion of the perturbations of Uranus has been referred to above, and Professor W. H. Pickering (*Harvard Annals*, lxi., part ii., 1909) has recently recast and extended this argument to make it serviceable for indicating the place of the perturbing planet, and reinforces his prediction by deriving the place of Neptune first from the errors of Uranus, and secondly from those of Saturn, with the help only of elementary common-sense considerations. It is difficult to judge of the validity of an argument which in substance amounts to a summary integration of a complicated differential equation, but, given the necessary material, the dynamical points seem to the present writer sound. Unfortunately the difficulty arises in getting the material in suitable shape, and it is hard to feel convinced by the confirmatory examples. From Hill's theory it appears that the chief periodic disturbance of Saturn by Neptune has an amplitude of less than 2″. The residuals which

Professor Pickering's method supplies him with run up to 24″. Whatever be the origin of these, they are not due to Neptune; and if they indicate his place, it must be by an accident. Coming to the perturbations of Uranus, their character is at present clearly known. Far the greater part of them is due to a long inequality of the first order of period over 4000 years, which, relatively to the osculating elements at any epoch, produces an acceleration of mean motion and a continuous change in the eccentricity and the position of the apse. The other periodic perturbations are relatively trifling; they might perhaps sometimes reach 60″, but in conjunction their sum never exceeds 20″. Within the period of observation the long inequality amounts to 200″ or more, and if it is disregarded, whatever epoch we take for the osculating elements, the observations will gradually faster and faster work away from the corresponding ellipse. Herschel, by a graphical process, corrects Bouvard's mean motion, eccentricity and longitude of perihelion, leaving a well-marked hump in the residuals which reaches a maximum in 1822. So far as this is successful, it is equivalent to choosing a different epoch for osculation. Pickering's method is so far the same, but his choice shows a maximum of 86″ in 1826. If 1822 or so in place of 1750 had been made the epoch of osculation, the hump in the residuals would have shifted right away from the former date to the latter. The success of Pickering's following steps depends upon assigning a definite inevitable position to this hump, and connecting it with the maximum effect in longitude of the perturbative tangential and radial forces about conjunction. The apex of the hump, after some allowances, is taken as corresponding with conjunction, which is thus determined. If the remarks above are correct there is no such inevitable position, but, apart from this, it must be doubtful whether a graphical method that involves the simultaneous estimation of three unknowns is satisfactory. If one is unbiassed it will often be impossible to decide between different settings. These considerations take away much from the weight of Professor Pickering's confirmatory examples.

The material which he uses for searching for the evidence of a new planet—"O"—consists in the deviations of the observations of Uranus from the tables. Neptune is not relied upon, for the reasons mentioned above. In order to get a sufficient span of time, the tables employed are those of Leverrier; and as these are less accurate than Newcomb's, a part of the deviations must be due to this cause, but how much does not appear. Their greatest and least values are +4″·2 in 1861 and −3″·3 in 1895. Correcting them graphically as before, the conclusion is reached that they leave residuals which correspond with the perturbations of an exterior planet in long. 105°·8 at epoch 1900, with mean motion 0°·964 per year, and mean distance 51·9. In conclusion, it may be mentioned that a search has been made in this region at Arequipa. (*Harvard Circular*, 144.)

R. A. S.

Solar Activity in 1909.

Sun-spots.—The mean daily numbers and areas of sun-spots showed very little change in 1909 from those recorded in 1908; there was, indeed, a slight diminution on the whole, but this was entirely due to the great activity observed during 1908 August. Omitting that month, the record for 1909 would considerably exceed that for 1908.

The year 1909 opened with quite a marked revival of sun-spot activity, which then gradually declined pretty steadily, though with some minor fluctuations, until the end of August, when a marked secondary minimum occurred. This was followed in September by a sharp recovery, after which there was another gradual and steady decline, lasting until the end of the year.

The faculæ showed, as in the preceding years, much fewer and less marked fluctuations than the spots, and testified to a distinct but not very large falling off as compared with 1908. It is therefore clear that the maximum is past, though the decline towards the minimum is as yet proceeding very slowly.

The sun-spot group of greatest interest during the year 1909 was group 6728 of the Greenwich series. A short stream of small spots was seen on August 29, 30, and 31, as group 6719, but died out before reaching the west limb. When the same region had come round to the east limb in the next rotation it was marked by a very large composite spot, group 6728, which underwent frequent and striking changes of shape, and displayed much activity, as examined by the spectroscope. It crossed the central meridian of the disc on September 23, 19^h G.C.T., and continued to develop in size until it reached the west limb. Shortly after it crossed the central meridian there broke out the most intense magnetic storm experienced for more than a third of a century, the violent phase beginning sharply soon after 11^h a.m. on September 25. In the next rotation the group 6728 returned as a "procession" of three groups, the central one, group 6746, being much the most considerable, although very greatly diminished from its former size. It crossed the central meridian on October 20, 17^h G.C.T., and a considerable magnetic disturbance followed at midnight on October 22.

Another important group was one that had commenced its life on 1908 November 7, and was seen in seven successive rotations gradually disappearing soon after it had crossed the central meridian for the seventh time on 1909 April 23, and being last seen on 1909 April 25. It had thus lasted for 170 days, and was the group of longest duration in the Greenwich records.

Although visible to the naked eye soon after its first formation, this long-lived group had diminished below this rank before its second appearance, and it is not therefore to be included amongst the "naked-eye" groups of 1909. The latter were not numerous. The months of February, March, May, and July each afforded one

example, and September three. The most remarkable group as to appearance was No. 6738, crossing the central meridian on 1909 October 10. This was of quite unusual form, an immense number of small spots being loosely scattered over a wide area, and not drawn out into a stream. The majority of the groups were either single circular spots, regular in form, and stable in character, or else small streams of normal type. There were only one or two examples of "processions" of groups closely following each other along a parallel of solar latitude, and these were less extended than was the case in 1907. The general type of disturbance, therefore, was much quieter than in the three years of the maximum, 1905–6–7, although, as yet, the decline towards the minimum has not proceeded far.

The mean latitude for spots in the southern hemisphere was about 12°, in the northern hemisphere about 10°. E. W. M.

Prominences.—The daily frequency of prominences during the year 1909, as deduced from spectroheliograms taken on 45 days included between the months April and September, is as follows:—

N. Hemisphere . . .	2·9
S. ,, . . .	2·7
Whole	5·6

The photographs used were secured in "K" (calcium) light by means of the spectroheliograph of the Solar Physics Observatory, S. Kensington. The minimum height of prominence taken into account was about 20″.

The total activity remains about the same as that deduced from last year's data, but in 1909 there was a slight preponderance of activity in the northern hemisphere. Activity at the poles was not very marked, but was well maintained in the low-latitude spot zones. Owing to the small number of photographs available for discussion, the distribution of the prominences in zones of 5 or 10 degrees is not attempted here.

In order to form a comparative, though only an approximate, view of the state of prominence activity in 1909 with that of former years, the data for the previous four years, deduced exclusively from the S. Kensington photographs, are given below:—

	1905.	1906.	1907.	1908.	1909.
N. Hemisphere . .	3·4	3·9	3·5	2·5	2·9
S. ,, . .	3·0	2·6	3·9	3·1	2·7
Whole	6·4	6·5	7·4	5·6	5·6

The above values may with interest be compared with the final values of the mean daily frequencies, as deduced at Kodaikánal

from a considerable number of photographs taken during the years 1905–1908. They are as follows:—

	1905.	1906.	1907.	1908.
N. Hemisphere	7·8	8·6	8·9	8·9
S. ,, ...	7·8	8·2	10·7	10·0
Whole	15·6	16·8	19·6	18·9

In the above Kodaikánal table the minimum height of prominences included is 10″: this accounts for the much larger values of the mean frequencies given. W. J. S. L.

Solar Research in 1909.

Sun-spot Spectra.—The possible occurrence of water vapour in sun-spots has been investigated by Evershed, who finds the evidence overwhelmingly against its presence (*Observatory*, xxxii. 102). Dr. W. M. Mitchell also considers that there is no substantial evidence of the existence of water vapour in spots (*Ap. J.*, xxx. 44).

In another paper Dr. Mitchell describes a form of solar spectroscope which he has adapted to the 10-inch equatorial at Haverford College (*Ap. J.*, xxx. 75). A grating spectroscope of Littrow form is fixed in a position parallel to the main telescope, and after enlargement by a negative lens, the solar image is reflected on the slit by a right-angled prism, and thence the rays are sent along the spectroscope by another diagonal prism. In this way a very powerful instrument was constructed at very small cost. The actual resolving power in the third order was no less than 70,000, and it was found possible to verify Hale's photographic determinations of the Zeeman effects in sun-spots by direct observations.

A valuable summary of the work at Mount Wilson relating to the spectra of sun-spots is given by Mr. W. S. Adams (*Ap. J.*, xxx. 86). The main results are thus stated: "(1) A discussion of the various elements whose lines are strengthened or weakened in the spot spectrum indicates that the changes observed may be best accounted for on the basis of a reduced temperature in spots; (2) The presence of the spectra of titanium oxide, magnesium hydride, and calcium hydride is sufficient to account for the greater part of the unknown fluting and band lines appearing in the spot spectrum; (3) The discovery of the existence of a magnetic field in sun-spots by Prof. Hale provides a ready and sufficient explanation for the widening of large numbers of lines in the spot spectrum for which there is no marked change of

intensity." Independent evidence which is considered to be in favour of low temperature in spots is afforded by the behaviour of the hydrogen lines, which indicate a marked shift of the maximum of intensity towards longer wave-lengths. Incidentally, it is mentioned that the presence of flutings is unlikely to be due to increased pressure, because the Mount Wilson observations agree with those of Evershed in showing that the excess of pressure in spots over that on the surface of the Sun can hardly be as much as one atmosphere. Of the 8100 "unknown" lines in the spot spectrum between λ 4000 and λ 7000, nearly 80 per cent. are accounted for by the three compounds already mentioned. The paper also gives a complete list of the doublets and triplets, due to the magnetic field, which have so far been identified.

Further experiments on the behaviour of iron and titanium lines when the source is placed in a strong magnetic field have been carried out at Mount Wilson by King, with special reference to certain lines in sun-spots which appeared to be abnormal in their behaviour. In the less refrangible part of the spectrum the agreement between experiment and observation is close enough to suggest that the magnetic field of a sun-spot is of such a character that much of the light comes to us at a large angle to the lines of force (*Ap. J.*, xxix. 76 and xxx. 1). It is found that enhanced lines do not form a special class in regard to their behaviour in a magnetic field.

A detailed investigation of the magnesium hydride spectrum, with nearly 2000 wave-length measurements, has been published by Fowler (*Phil. Trans.*, 209 A, 447). The occurrence of magnesium hydride in the spot spectrum is fully demonstrated, but its presence in the ordinary solar spectrum is considered doubtful.

In view of the presence of magnesium and calcium hydrides in spots, a search for the hydrides of barium and strontium has been made by A. Eagle. Definite banded spectra, which are attributed to these substances, were obtained, but no evidence of their presence in the spectra of sun-spots was found (*Ap. J.*, xxx. 231).

Tables of spectra which will be useful for comparison with spot spectra are given for titanium, in the region λ 5866 to λ 7364, by E. J. Evans (*Ap. J.*, xxix. 160); and for vanadium, in the same part of the spectrum, by H. Shaw (*Ap. J.*, xxx. 127).

An important discovery relating to radial movements of the vapours in sun-spots has been made by Evershed (*M.N.*, lxix. 454). When the slit of the spectrograph bisects a spot, and lies in the direction of the Sun's centre, the spectrum lines are quite straight over the spot, but are slightly inclined as compared with lines in the neighbouring photosphere; in the centre of the umbra there is no displacement, and the inclined lines end abruptly at the edge of the penumbra. The inclination is always such that displacement towards the red corresponds with the side of the spot nearest the limb, and it vanishes when the slit lies in a direction at right angles to the line joining the spot with the Sun's centre. Telluric

lines show no inclination whatever. In explanation of the observations, Mr. Evershed supposes a motion of the spot vapours, parallel to the Sun's surface, radially outwards from the spot centre with accelerating velocity. The maximum velocity, at the outer edge of the penumbra, is about 2 kilometres per second. The radial structure of the filaments in the penumbræ of spots is perhaps associated with this outward movement of the spot vapours. In a further note (*Observatory*, xxxii. 291), Mr. Evershed refers to the fact that when the slit is placed across the penumbra on the side of the spot nearest the centre of the disc, the lines are invariably convex towards the violet, and on the limb side the displacement is always towards the red, as would be expected. The absorption-lines H_3 and K_3 indicate an *inward* movement of the gases. Interesting comments on Mr. Evershed's work in this direction have been made by Mr. Buss (*Observatory*, xxxii. 213, 359).

Some further interesting contributions to the discussion of matters relating to the temperature and pressure in sun-spots have been made by Professor Whittaker (*Observatory*, xxxii. 57, 177, and 292), Father Cortie (*ibid.*, 60), and Mr. Evershed (*ibid.*, 135, 254, 362). Professor Whittaker argues that the stimulus which causes atoms to emit line-spectra appears to have no direct connection with temperature in the strict sense of the word, but to be primarily electrical in its nature, and that the condition specially favouring the production of arc lines is a relatively large vapour-density, while a lower vapour-density and strong electrical stimulus favour the production of spark lines. Mr. Evershed does not consider that it has ever been demonstrated that electrical or chemical "luminescence" is really a non-thermal effect. Father Cortie points out that in certain cases spectra occurring at high temperatures may belong to compounds which exist only at elevated temperatures, but nevertheless, from the varying band spectrum of Mira at different maxima, he concludes that a sun-spot is a region of reduced temperature and of greater density, in the sense of quantity of cooled material. In opposition to Professor Whittaker, Mr. Evershed maintains that the absence of "pressure shifts" in the reversing layer implies low pressure in that region. In view of the probability that the absorbing gases exterior to the photosphere are subject to an outward radial force, Mr. Evershed considers the ordinary calculations of pressure at the photospheric level to be entirely misleading.

An important account of the work on the spectra of sun-spots at Kodaikánal has been issued by Evershed as vol. i. part 1 of the *Memoirs of the Kodaikánal Observatory*. It includes the work on radial motion and pressure to which reference has been made above, together with a catalogue showing the behaviour of 1043 lines, and a photographic map of the spot spectrum between 4838 and 5723. The spectrum appears to be the same for all spots, and there is no evidence of change with time. A conclusion of great interest is to the effect that the general absorption in spots is

strictly continuous and similar in character to the absorption at the limb; in other words, the apparent bright gaps in the spot spectrum are mere contrast effects. Mr. Evershed is inclined to regard the spot spectrum as the fundamental spectrum of the cooler gases which are always slowly subsiding over the photosphere generally; so that, on this view, "a spot is a region where the photosphere does not exist, or has been thrust aside, revealing the solar atmosphere as it would appear were there no ascending jets of relatively hot gases."

The Flash Spectrum.—A noteworthy application of the great instruments at Mount Wilson during the past year was to the photography of the flash spectrum without an eclipse. Provisional values have been given for the wave-lengths of the numerous lines which have been photographed, including the components of the green carbon fluting beginning at 5165, and it is shown that they coincide very closely in position with Fraunhofer lines as measured by Rowland (*Ap. J.*, xxx. 222).

Solar and Magnetic Disturbances.—Several interesting solar observations about the time of the great magnetic storm of September 25, 1909, have been recorded. A sun-spot, which was then a little past the central meridian, showed marked activity when spectroscopically observed. Details will be found in the following papers:—Dr. Chree (*Nature*, lxxxi. 396); A. Fowler (*Nature*, lxxxi. 396); E. Holmes (*Observatory*, xxxii. 396); A. A. Buss (*Observatory*, xxxii. 394); W. J. S. Lockyer (*Monthly Notices*, lxx. 12); Rev. A. L. Cortie (*Monthly Notices*, lxx. 19).

Mr. Michie Smith records that a violent disturbance observed with the spectroscope and spectroheliograph in the same spot on September 28, was accompanied by another well-marked magnetic disturbance, and that in this case the two disturbances were probably simultaneous (*M.N.*, lxx. 23).

The Sun's Rotation.—A report on the results of further spectroscopic observations of the Sun's rotation, made at Mount Wilson during 1908, has been published by Adams (*Ap. J.*, xxix. 110). The observations are opposed to the existence of a variation in the rotation rate between 1906 and 1908, at least in the spot zones, and also to a suggested three-year period of variation. Confirmation of the previous deduction that different lines give different velocities has also been obtained; lanthanum and cyanogen give low velocities, while high values are given by certain lines of manganese and iron; two "enhanced" lines show a tendency to indicate low values, and lines which are considerably strengthened at the Sun's limb give high values in general. Faye's equation for the varying rotation in different latitudes satisfies the observations to within at least 10° of the pole. For the H_α line, the observations again show a much higher velocity than for the reversing layer, and this velocity has not been found to

be quite uniform, as was stated in the previous preliminary report on this line, but to show a difference of over 1° per day between the equator and high latitudes. The different values given by different lines are considered to be due to differences of level of the corresponding vapours and gases in the solar atmosphere.

An investigation of the position of the Sun's axis, based upon observations by Peters in 1860–70, has been carried out by Professor Turner (*M.N.*, lxix. 487). The data fill the gap between the Carrington and Greenwich series.

The Spectroheliograph.—Work with the spectroheliograph, and with the modified form of the instrument which permits the wholesale registration of radial velocities over the Sun's disc, has been actively carried on by Deslandres and his assistants at Meudon (*C.R.*, cxlviii. 968, cxlix. 493, 521). An interesting account of the methods and results was given by M. Deslandres at the meeting of the Society in June (*Observatory*, xxxii. 282, 317). Special attention has been given to images in K_3 and H_α in relation to the persistent dark filaments of the upper strata.

A fine series of spectroheliograms, chiefly in H_α, has been presented by Fox and Abetti, in illustration of the occasional appearance of associated northern and southern spots (*Ap. J.*, xxix. 40). In the case of two such spots, when observed on 1908 September 10, there was a marked disturbance, during which the spots were connected by flocculi, and a magnetic storm was recorded twenty-six hours later. Under normal conditions the interaction may possibly be confined to action below the photosphere.

Useful summaries relating to "Solar Vortices and Magnetic Fields" are given in reports of two lectures by Professor Hale (*Nature*, lxxxii. 20, 50; *Observatory*, xxxii. 311).

Professor Hale remarks that the images of dark hydrogen flocculi on spectroheliograph pictures taken with the second slit about equal in width to H_α appear to be due to local increases of intensity of the dark line, probably as a result of increased absorption (*Proc. Roy. Soc.*, vol. lxxxiii. A, p. 177). Evidence is given for the conclusion that anomalous dispersion is not the prime factor in producing the hydrogen flocculi, though it may play a secondary part in modifying their form.

The nearly complete obliteration of a sun-spot by calcium flocculi prior to the magnetic storm of 1909 September 25 is admirably illustrated by a series of photographs taken at the Solar Physics Observatory, South Kensington (*M.N.*, lxx. 12).

The Solar Constant and Temperature of the Sun.—Further discussion of observations of solar radiation has led Abbot and Fowle to estimate the effective solar temperature as not far from 6200° C. absolute (*Ap. J.*, xxix. 281). In 1908 the intensity of violet rays in sunlight was notably less as compared with the red rays than in 1906, though there was no change in the Sun's total emission.

From a series of observations at various altitudes from Meudon to the summit of Mont Blanc, made with a pyrometric telescope, Dr. Féry deduces 5920° absolute as the mean temperature of the Sun, but gives reasons for supposing that this may be too high a value (*M.N.*, lxix. 611).

Pressure in the Reversing Layer.—Fabry and Buisson have applied interference methods to a comparison of terrestrial and solar wave-lengths; and on the assumption that the average displacement is due to difference of pressure, it results that the pressure of the reversing layer in the region of iron absorption is between 5 and 6 atmospheres (*C.R.*, 1909 March 15). Pressure effects do not seem to account completely for the observed displacements, and in another paper (*C.R.*, 1909 May 10), referring to comparisons with the iron arc *in vacuo*—in which case all the lines are much sharper—the view that the discrepancies are due to unsymmetrical broadening in the ordinary arc is considered to be confirmed.

These conclusions of Fabry and Buisson are not accepted by Evershed, who has investigated the question on the basis of the differential displacements of lines which are little and much affected by pressure (*Kod. Bull.* xviii.). In this way the numerous corrections which should be applied when the absolute method is employed are eliminated, and Mr. Evershed does not consider it possible that the pressure in the reversing layer can exceed one atmosphere.

Fabry and Buisson have also confirmed the observations of Hale and Adams, and those of Halm, as to the differences in wave-lengths of lines at the centre and limb of the Sun (*C.R.*, cxlviii. 1741). There is a general increase in wave-length from 0·004 to 0·006 tenth-metres in passing from centre to limb, and an average increase in breadth of 0·01 tenth-metre. The difference is attributed to the excess of effective absorption by the denser strata when the limb is under observation.

Miscellaneous. — Two remarkable prominences observed at Zô-se on 1908 July 30 and 31 have been described by Chevalier. In addition to many of the usual bright lines, two strange lines at 5872·50 and 5879·9 were noted, together with a strong continuous spectrum (*Mem. Soc. Spett. Ital.*, xxxviii. 2).

Professor Perrine concludes that the brightest parts of the corona in 1905 and 1908 were actinically brighter than the surrounding sky in the ratio of 744 to 1, and that the total coronal light was 0·111 times that of the full moon (*L.O.B.* 153).

Further extensive observations of dark D_3 in the neighbourhood of sun-spots during 1908 are reported by Capt. Daunt (*M.N.*, lxix. 605).

A. F.

Double Stars.

The abbreviations used are —

M.N. : *Monthly Notices.*
A.N. : *Astronomische Nachrichten.*
L.O.B. : *Lick Observatory Bulletin.*
B.A.A. : *Journal of the British Astronomical Association.*

Of new double stars, the Rev. T. E. Espin contributes 140 pairs, discovered with the 13-inch reflector. These are in *M.N.*, 1909 January and May. There are 61 under 5″ separation and 79 over 5″.

Ten pairs, found by R. Jonckheere, are in the *Journal Astronomique*, Nos. 1, 2, 3.

E. E. Barnard, *A.N.* 4306, gives 3 close pairs.

Dr. R. G. Aitken, by the addition of 200 new pairs, *L.O.B.* 158 and 171, brings his total discoveries up to 2100. Of these, 659 are under 0″·5 separation.

Professor Burnham, following his measures in *A.N.* 4209 and 4261, gives two further sets of measures in *A.N.* 4301–2 and 4353–4. These measures of about 600 stars were made with the 40-inch Yerkes refractor. They are mostly of faint stars at some distance from the bright star, and are measured with the object of obtaining better material for proper motion of the bright stars than can be secured from meridian observations. There are a few close pairs and pairs of interest—

Sirius	1908·86	94°·2	8″·70
40 Eridani	1908·83	42°·6	2″·57

With the same instrument and also the 12-inch refractor P. Fox has measured 140 miscellaneous pairs which are published in *A.N.* 4336. There are 26 under 2″ separation.

Dr. Doberck has lost no time in setting up his refractor at Sutton, and in *A.N.* 4328 he gives a first set of measures of 310 pairs showing motion.

On the completion of the meridian observations of the stars in Gill's *Zodiacal Catalogue*, W. Valentiner thought it desirable to measure such as were double. The results are in *Publications of the Heidelberg Observatory*, No. xvi. The measures were made in 1908 and 1909; there are about 150 pairs, 40 being less than 10″ separation.

Dr. Valentiner, as Director of the Heidelberg Observatory, publishes a more important series of measures made by E. Przybyllok with the 12½-inch refractor. The measures are made from a carefully selected list of OΣ stars, pairs in motion and a few miscellaneous pairs, and will be found in *Veröffentlichungen der Grossherzoglichen Sternwarte zu Heidelberg*. There are measures of 284 OΣ stars and 91 miscellaneous, forming a very useful set, especially the OΣ stars. The R.A.'s and Dec.'s are given for 1910.

In *A.N.* 4360 Messrs. Oliver, Wilson, and Newton-Neff publish

measures of 162 pairs made in 1908 and 1909 with the 66-cm. refractor at the Leander McCormick Observatory. They form a very useful contribution of southern stars, of which 100 are under 2″ separation.

Sirius 1909·06	93°·3	8″·62	N	5
1909·09	92°·0	8·56	O	4

M. Lau (Urania Sternwarte, Kopenhagen—24·6-cm. refractor), in *A.N.* 4315, gives a set of measures of 130 Struve pairs and a few miscellaneous wide pairs. A further series, made in conjunction with M. Luplau Janssen, is in *A.N.* 4378–79. In this set 150 are wide pairs ranging from 5″ to 240″ separation. Forty pairs are under 5″ separation, and include 42 Comæ, τ Ophiuchi, γ Coronæ Bor., and Σ 1639.

In *M.N.*, 1909 May, there is the annual list of measures from the Royal Observatory, Greenwich, made with the 28-inch refractor. As usual in recent years, only the measures of pairs under 4″ separation are given. The present list contains 500 pairs, the complete measures being published in the Greenwich annual volumes. These are from a working catalogue of pairs in motion and close new pairs.

The Cambridge University Press have published in the *Cambridge Observations*, vol. xxiv. part i., the "Measures of Double Stars made with the Northumberland Equatorial of the Cambridge Observatory in the years 1839 to 1844." This is a series of hitherto unpublished measures made by Challis and Glaisher. There are about 500 pairs—mostly W. Struve—and their value is enhanced from the fact that in many instances they are the only measures coming between those of W. Struve and Maedler. The measures were first collected by Mr. Lewis, and were prepared for press under the direction of Sir Robert Ball.

In the Society's *Memoirs*, vol. lvii., is a set of measures of 64 pairs by Mr. Maw during the years 1900–1907, with a 6-inch refractor at Kensington, and an 8-inch at Outwood, Surrey. Mr. Maw's measures now cover a period of 20 years. There are 45 pairs under 2″ and 19 pairs over 2″ separation.

M. Lau, in *A.N.* 4298–99, discusses the systematic errors in double-star measures. Taking the measures in vol. lvi. of the Society's *Memoirs*, he deduces some interesting and surprising results. Thus the probable error of a measure and the constant or systematic error are—

	P. Error.	Constant Error.
Dembowski	±0°·65 , ±″·072	−0°·40 , −″·028
Seabroke	±0·85 , ±·110	
Doberck	±0·86 , ±·129	+0·52 , −·008
Burnham	±0·88 , ±·100	−0·31 , −·053
Aitken	±0·90 , ±·065	−2·01 , +·101

M. Lau also investigates the errors due to position-angle.

Dr. Doberck, in *A.N.* 4306, discusses the distances, as estimated,

between close pairs in Sir W. Herschel's published observations. He shows that estimates of pairs below 2″ separation were very accurate; but when the separation reached 6″ the error became considerable, often amounting to several seconds.

Dr. Aitken, in *A.S.P.* 1908 December, has a note of the parallax and proper motion of Krueger 60.

Karl Böhlin, *A.N.* 4365, gives the parallax of Σ 2398 as +0″·251.

M. Lau, *Bulletin Astronomique*, 1909 December, has a long discussion of the motion of the system 70 Ophiuchi. He establishes the existence of large periodic errors, proves that they cannot arise from systematic errors of observations, nor from a hypothetical dark body. He is content to adopt an empirical formula $\Delta p = 0^{\circ}\cdot5 + 1^{\circ}\cdot0 \sin 2p$, to represent the fluctuations in position-angle.

J. Nangle, *B.A.A.* xix. No. 9, collects the measures of p Eridani and gives a provisional orbit. In *B.A.A.* xx. No. 1 he discusses the measures, motion, and variability of Lacaille 7145.

Rev. T. Roseby, *B.A.A.* xx. No. 1, gives history and discussion of α Crucis.

In *Popular Astronomy*, 1909 May, Willis L. Barnes describes an easy graphical method of determining the most probable apparent orbit of a double star.

Dr. Doberck gives the result of a discussion of the system ζ Cancri in *A.N.* 4273. He considers the existence of an invisible body as established, and that the companion C moves round it in a circle of radius 0″·158 in a period of 17·43 years.

Professor J. B. Dale, *M.N.*, 1909 June, suggests a method of making measures of double stars which will eliminate systematic errors from the results. He illustrates his paper with measures of γ Leonis.

In *The Observatory*, No. 406, Professor Karl Pearson discusses the correlation between various data of double stars, such as magnitudes and colour, period and major-axis. T. L.

Variable Stars.

One has only to glance over the leading astronomical periodicals to note what a considerable place the observations and theory of variable stars now occupy in them. It is possible only to take note of some of the more prominent points in connection with the work of the past year.

The total number of new variable stars registered by the Committee of the *A.G.* for 1908 was 175; for 1909, up to the time of writing, 44 new discoveries are announced. Of the latter, 22 are due to Harvard College Observatory, 13 to Ceraski at Moscow, the remainder being distributed among several observers.

The permanent lettering of 62 new variables is given in *A.N.* 4364. We notice the combinations AB, AC in Cygnus,

showing the large number of variables now known in that constellation, the combination of two letters commencing with R, S, etc., being exhausted.

In addition to the numerous visual observations of variables, we find photometric determinations now being made at the Royal Observatory, Padua (*A.N.* 4331), at Potsdam (*A.N.* 4352 and 4373), and at Heidelberg (*A.N.* 4367). This, of course, is additional to the photometric work permanently carried on at Harvard.

Twenty new variable stars in Harvard Map 49 are announced in *H.C.* 151.

Mr. T. H. Astbury has discovered an Algol Type Variable, of which the provisional number is 13, 1909 Vulpeculæ, corresponding to B.D. $+22^{\circ}$, 3617 (7·5 m). Variation rather more than half a magnitude. *A.N.* 4321.

S. Blazko gives physical details of the system U Cephei in *A.N.* 4338.

Astbury gives the elements of the Algol Variable Z (26, 1900) Vulpeculæ as Min. = 1908 Dec. $9^{d}\,6^{h}\,0^{m}$ (241, 8285.250) + $2^{d}\cdot455$ E (*A.N.* 4367).

In *H.C.* 151, Professor E. C. Pickering gives particulars of the variable *SU Tauri*. At full brightness it is about 10·3 m., but at minimum is <12 or even <13 m. The light curve resembles that of *R Coronæ Borealis* in having long periods of normal light with sudden diminutions of large range, similar in type to the rare class of variables of which only R Coronæ and RY Sagittarii (discovered by Markwick) have hitherto been known.

Among light curves illustrated graphically, the following are worthy of notice:—

TT Cygni, by *Esch.*—This shows a sharp peak at maximum, with flat curve at minimum. *A.N.* 4325.

SX Cassiopeiæ, by *Luizet.*—This is of the β Lyræ type of variation. *A.N.* 4339.

VZ Cygni, by *Luizet.*—Type of T Monocerotis. *A.N.* 4340.

11, 1908 Orionis.—From photometric observations by *Münch* at Potsdam. Type of δ Cephei. *A.N.* 4352.

78, 1907 Aurigæ.—Possibly β Lyræ type, but flat at maximum. *A.N.* 4352.

o Mira Ceti in 1908, by *Nijland.*—This curve shows a small difference in scale for the finder and the binocular.

S Sagittæ.—An interesting chart of the photographic observations by *Hertzsprung* is given in *A.N.* 4362. It accords closely with that determined visually by the *Variable Star Section* of the B.A.A. (*Journal B.A.A.*, vol. xvii. p. 210).

U Herculis, by *S. Enebo.*—β Lyræ type. The variation was formerly supposed to be irregular. *A.N.* 4363.

Among the numerous publications in the form of *Annals of the H.C.O.*, we may briefly refer to the following:—

Vol. lvii. part 2.—Comparison stars for 252 variables of long

period. A very useful work for the observer, giving the positions and magnitudes of the stars required.

Vol. lxiv. 4.—A discussion of the Revised Harvard Photometry. It is stated that the observations contained in the various photometric catalogues agree closely in scale, and that they are independently confirmed by the Oxford and Potsdam catalogues. It also appears probable that the scale of the meridian photometer agrees closely with the true photometric scale. The principal deviation is that of the Potsdam observations, where blue stars measure about three-tenths of a magnitude fainter than red as compared with other catalogues.

Vol. lxiv. 6.—A catalogue of the photometric magnitudes of the components of 619 double stars. This should be a help in double-star work, where it is notorious the assessment of stellar magnitudes is made under conditions of considerable difficulty.

No. 57 of the *Publications of the Potsdam Observatory* consists of an interesting Memoir on the Variable R Coronæ Borealis by H. Ludendorff. All the important observations of the star are given, commencing with those of Pigott in July 1783, and extending to September 1905. The normal light, the curiously irregular minima, and the spectrum of the star are fully discussed. The work is illustrated by a series of plates, which show at a glance the fluctuations of light from 1843 to 1905. E. E. M.

Stellar Distribution and Drift.

The investigation of the systematic motions of the stars has made considerable progress during the past year. Professor Dyson (*Proc. Roy. Soc. Edin.*, xxix. p. 376) continues his discussion of the stars having proper motions greater than 20″ per century. There is considerable difficulty in treating statistics of *selected* motions, but by comparing the distribution of the motions of the stars of the two streams at various distances from their respective apices, it was found possible to compare the velocities of the two streams. Dyson deduces that the velocities of stream I. and stream II. are in the proportion 3 : 2. This differs considerably from Eddington's determination (about 3 : 1) from the Groombridge proper motions. There is a consequent disagreement in the position of the *vertex* (or direction of motion of one stream relative to the other), Dyson finding for this point the position R.A. 88° Dec. + 24°, which differs about 18° from the place obtained from the Groombridge stars. It is, however, noteworthy that Dyson's result agrees well with a determination by Beljawski, according to Schwarzschild's ellipsoidal hypothesis, which was also based on the large proper motions.

On the other hand, the results from the Groombridge stars are supported by an investigation by Dr. K. Rudolf (*Ast. Nach.* 4369), in which he has determined the vertex and apex from the stars of Bradley's Catalogue. Using the ellipsoidal hypothesis, he derives

for the vertex the position R.A. 96° Dec. + 7°, agreeing very closely with Schwarzschild and Eddington. His value of the ellipticity of the velocities-ellipsoid is also in complete agreement.

There is thus at present a difficulty in reconciling the results from the large proper motions with those from the small proper motions. Both the corresponding vertices lie accurately in the plane of the Milky Way, but differ about 18° in galactic longitude. The certainty with which the directions of the large proper motions can be determined, and their freedom from the influence of systematic error, as well as the advantage of including proper motions from all parts of the sky, would lead us to attach the greatest weight to Dyson's and Beljawski's result; but, on the other hand, their investigations are, from the nature of the data, limited to the stars in the immediate neighbourhood of the Sun, which may perhaps not be fairly representative of the great bulk of the stars to which the two-drift and ellipsoidal hypotheses apply.

The first examination of the radial velocities of stars for evidences of the two star-streams has been made by Mr. Hough and Dr. Halm (*Monthly Notices*, lxx. p. 85). They made use of 166 stars whose radial motions were measured at the Cape, together with 280 determined at Lick and 45 from miscellaneous sources. After determining and eliminating the solar motion, the residuals were found to vary systematically in different parts of the sky. The phenomenon can be explained by supposing that the two star-streams are not everywhere in the same relative proportions. On this hypothesis a determination of the position of the vertex was made; the result R.A. 88° Dec. + 27° agrees very closely with the determinations of Dyson and Beljawski. It is found, further, that the proportion of drift II. stars is a maximum at R.A. 324° Dec − 12° and a minimum at the opposite point of the sky.

In *Gröningen Publications* No. 23 is published a photographic determination of the parallax of the Hyades, the result of the co-operation of Professors Donner, Küstner, Kapteyn, and de Sitter. In an investigation described in the Council Note last year, Professor Boss had found that 39 bright stars in this region have motions accurately converging to a point on the sphere. The knowledge of this point, together with the proper motion and radial velocity of a few of the group-stars, made it possible to determine the parallax of the group indirectly. Boss's mean result was $0''{\cdot}0253$. The present direct determination gives $0''{\cdot}023 \pm 0''{\cdot}0025$. Professor Kapteyn concludes, "It is my conviction that by the work of Professor Boss, together with that of the present publication, the parallax of the group of the Hyades, notwithstanding its small amount, has been established within as small a fraction of the whole as the parallax of almost any star in the sky."

Attention has also been directed to the somewhat similar group of Ursa Major stars which have a common motion. Dr. H. Ludendorff (*Ast. Nach.* 4313–14) has made determinations of the radial velocities of β, ϵ, and ζ Ursæ Majoris, and hence derived the

motion and parallax of the group. Dr. Ejnar Hertzsprung (*Ap. J.*, xxx. p. 135) has found a number of other stars in widely different parts of the sky, which appear with more or less probability to be associated with the group. The evidence is most certain in the case of Sirius, whose parallax and radial velocity are well determined, and agree with the computed values. A further investigation by Ludendorff, with special reference to the binary star β Aurigae, another probable member of the group, appears in *Ast. Nach.* 4376.

Professor Turner (*M.N.*, lxix. p. 495) has extended his search for large proper motions in the Oxford zone, and has now compared forty duplicated plates, containing nearly 10,000 stars. Of these, 26 have annual proper motions greater than $0''{\cdot}2$. As is the case with the brighter stars, the large proper motions are distributed nearly uniformly, with no condensation towards the Milky Way.

Professor Barnard (*Ast. Nach.* 4363) discusses the relative motions of the stars of the cluster Messier 92 (Hercules), based on a comparison of measures, both photographic and visual, made about eight years apart. This work shows that the motions for the most part must be very small; the large motions in this cluster found by Bohlin were not substantiated. There are, however, two stars which form exceptions to the prevailing rule of small motions; their centennial proper motions are $8''{\cdot}3$ and $6''{\cdot}5$ respectively.

A. S. E.

The Absorption of Light in Space.

The problem of determining the distribution of the stars in space, and in particular the question whether any thinning out in the distribution can be detected when a great distance is reached, is very closely bound up with the question of the absorption or scattering of light in space. In two papers (*Astrophysical Journal*, xxix. p. 46 and xxx. p. 284) Professor Kapteyn has given a full discussion of the question, which indicates the methods by which we may hope to arrive at a solution, although the numerical results derived from data at present available can hardly be regarded as more than tentative. If there exists through space finely divided meteoric matter in quantity sufficient to cause appreciable absorption of light, this will be shown by the fact that, *cæteris paribus*, the more distant stars will appear redder than the nearer ones, owing to the light at the violet end of the spectrum undergoing greater scattering than the less refrangible rays. In his first paper Kapteyn calls attention to Miss Maury's division of the stars of spectral class XVa into two groups typified by Arcturus and α Cassiopeiæ, of which the latter shows a stronger general absorption in the violet than the former. On comparing the proper motions of the stars of the two groups, it is found that those of the α Cassiopeiæ group are much the smaller; consequently it may be

inferred that they are more distant on the average. Thus it appears that the stars which show the strongest relative absorption in the violet are the most distant, a result favouring the hypothesis of the absorption of light in space. An alternative explanation, though perhaps improbable, must, however, be considered: as both groups of stars are of about the same apparent magnitude, if they differ in distance they must also differ in actual size or luminosity. It is not impossible that there may be some interdependence between the size of a star and the redness of the emitted light. In the second paper Kapteyn discusses data relating to 1433 stars for which visual and photographic magnitudes, spectral class and proper motion are known. The redness, which is measured by the difference between the Harvard visual and photographic magnitudes, is regarded as varying with three conditions (for stars of the same spectral class)—(1) the distance of the star, and consequent amount of space-absorption; (2) the absolute luminosity of the star; (3) the apparent magnitude. The variation with the apparent magnitude is of course not a cosmical phenomenon, but must be dependent on the peculiarities of the determination of visual or photographic magnitude. Equations were formed and least-squares solutions made to determine the dependence of the redness on each of the three causes, and a definite small space absorption appeared to be indicated. If it is assumed that the whole loss of light is by scattering, the results (after applying a correction given on p. 399) show an absorption in a distance of 32·6 light years (equivalent to a parallax 0″·1),

for the photographic rays = ·0055 magnitude
„ visual „ = ·0027 „

There is no evidence of any difference in the amount of absorption in galactic and extra-galactic regions, so that the great richness in stars of the Milky Way does not appear to be due to smaller space absorption.

One of the evidences which indicates either space-absorption of light or a sparser distribution of the stars at great distances from the Sun is the deviation from its theoretical value 3·98 of the ratio of the number of stars of any magnitude to the number of a magnitude one unit brighter. In *Harvard Circular* 147 it is shown that there is a marked difference in this ratio for stars of different types of spectrum. Stars of types A and F follow closely the theoretical law, that is to say, the ratio for them is 3·98. For stars of types G, K, and M the ratio is 3·24. These results are derived from a discussion of the stars brighter than magnitude 6·5, and therefore do not apply to the faint stars; the region of the Milky Way was excluded from the investigation. Professor E. C. Pickering considers that absorption of light in space could not produce an effect on the star-ratio, which differs in this way for different kinds of spectrum.

Professor Turner's suggestion (*M.N.*, lxix. p. 61) that the well-known difficulty of bringing photographic exposures into accord

with our knowledge of the visual magnitudes of stars might be a cosmical phenomenon, depending on the scattering of light in space, and consequent increased redness of the fainter stars, has been examined by M. Tikhoff (*Comptes Rendus*, 148, p. 266) and by Mr. Parkhurst (*Ap. J.*, xxx. p. 33). The former obtains results completely in accord with the suggestion. Mr. Parkhurst, however, does not confirm it, and concludes that photographic effects (depending on the kind of plate used) play so important a part in the matter as to completely mask cosmical causes.

It seems to be now generally conceded that the observations of Nordmann and Tikhoff, which were at first believed to show a dispersion of light in interstellar space, do not admit of this explanation. A dispersive medium must almost necessarily be an absorbing medium; and one of the difficulties of accepting the hypothesis lay in the fact that on any ordinary theory the required dispersion would be accompanied by an amount of absorption that was obviously inadmissible. M. Lebedew (*Ap. J.*, xxix. p. 101) discusses the question, and argues that the phenomenon (which is not disputed) should be ascribed to tidal changes in the emitted light of the variable stars. A. S. E.

Recent Researches on Space, Time, and Force.

Celestial mechanics, which has hitherto been based on the Newtonian laws of motion, is profoundly affected by the discoveries which have been made in recent years regarding measurements of space, time, and force.

One of the oldest and most perplexing questions regarding space is whether any definite meaning can be attached to the terms "absolute rest" and "absolute velocity." Newton in the laws of motion speaks of "rest" and "motion" relative to some presupposed frame of reference; but this frame of reference need not itself be absolutely at rest, for Newton's laws are valid if the frame of reference is any one of an infinite number of frames which have uniform velocities of translation relative to each other. It is therefore hopeless to look to purely dynamical considerations for guidance in the recognition of absolute rest.

Throughout the nineteenth century it was thought that absolute motion in space, or at any rate absolute motion relative to the general body of stars, could be determined by the astronomical study of proper motions; and the Sun was supposed to have "an absolute velocity of about fifteen miles a second towards a point in the constellation Hercules." It is needless to relate here how this result has been overthrown by the labours of Kapteyn. But even when the failure of dynamics and astronomy to reveal absolute motion was admitted, it was still hoped that the solution might be found by aid of the theories of light and electricity. For suppose a luminous or electro-magnetic disturbance to be set up at a definite

instant of time at some definite point of space; the disturbance will travel outwards from this point as a wave-front, which, if the space is unoccupied by matter, will be a sphere of gradually increasing size. During this process the centre of the sphere preserves its position unchanged relative to the æther; and thus it would seem as if a definite meaning could be attached to the term "absolute rest." Hopes might even be entertained of the measurement of absolute velocities relative to the æther by experimental methods.

The example which has just been given belongs to the theory of light. It is not difficult to imagine also electrical systems which might be expected to give information regarding absolute motion. For instance, two electric charges repel each other according to the law of electrostatics; but if the charges are in motion with equal and parallel velocities at right angles to the line joining them, the moving charges will be equivalent to elements of parallel currents, and the electrostatic repulsion will consequently be weakened by an electro-dynamic attraction superposed on it. Absolute rest could thus be characterised as that state in which the force between the charges has its maximum value.

Numerous optical and electrical experiments based on principles similar to these have been made at different times with the object of determining the absolute velocity of the Earth. But the expected effect has always failed to show itself; and at last physicists have been driven to the conclusion that a previously unrecognised compensatory influence must exist, which removes all effects of motion through the æther from the quantities which are measurable in the experiments.

The nature of this compensatory influence was first discovered by Fitzgerald.* It is, that the dimensions of material bodies are slightly altered when they are in motion relative to the æther, the linear dimensions of a body in the direction of its motion being contracted in the ratio $(1 - w^2/c^2)^{\frac{1}{2}} : 1$, where w denotes the velocity of the body and c the velocity of light. For a body moving with the speed of the Earth the ratio w/c is only 1/10,000, so the contraction is only one two-hundred-millionth.

The full significance of Fitzgerald's hypothesis was only gradually unfolded. The first development was the discovery that if a purely *electrical* system is in equilibrium when at rest, the members of the same system will be in equilibrium when they have a common translatory motion, provided the system experiences an alteration of dimensions precisely the same as that which Fitzgerald attributed to *material* bodies. The obvious deduction from this is, that the forces of cohesion which determine the size of material bodies are really electrical in their origin: if this be accepted, the Fitzgerald contraction follows as a necessary consequence.

* *Nature*, xlvi. p. 165 (June 16, 1892). The hypothesis was adopted by Lorentz in a communication made to the Amsterdam Academy on November 26 of the same year.

It will be seen that under these circumstances we cannot hope to measure experimentally either the Fitzgerald contraction itself or any other effect of motion through the æther so long as we ourselves move with the moving system; for all these effects of motion form part of a general sympathetic change which takes place in everything with which we can operate, so that no alteration in the mutual relations of the members of the system is recognisable from within. The change, such as it is, is best described as a variation of the standards of length, time, and force.

It is this last-mentioned aspect of the matter which has chiefly occupied attention of late. On what principles are measurements of length, time, and force ultimately based?

It may be remarked that the measurement of space cannot be effected without introducing the idea of time, for of the events with which we deal in natural philosophy each is perceived to happen at some definite location at some definite instant of time, and we have no obvious means of preserving the identity of this location from one moment to another. Experience deals directly, not with a three-dimensional world of space, but with a four-dimensional world of time and space combined, and the choice of a system of measurement really means the choice of a particular *projection* of this four-dimensional world into a three-dimensional world of space and a one-dimensional world of time. In practice we perform this act of choice in such a way as to simplify the description of natural phenomena as much as possible; thus we lay down the condition that the increment of the time-variable in the interval between any two consecutive beats of a pendulum carried along with the observer shall be the same as its increment in the interval between any other two consecutive beats; by measuring time in this way we are enabled to formulate the laws of dynamics in simple terms.

We have already seen reason to suppose that the fundamental branch of physical science is the theory of the æther, and we are consequently led to measure space, time, and force in such a way as to give the simplest possible form to the laws of æthereal disturbance. Accordingly two philosophers, situated respectively on two stars which are in motion relative to each other, will not choose the same standards of length and time; each of them will in fact choose his standards so as to satisfy the condition that the velocity of propagation of æthereal disturbance, relative to a framework which moves with his own star, is to be reckoned equal in all directions.

The projection of the four-dimensional world of space and time into the three-dimensional world of space and the one-dimensional world of time is therefore really arbitrary; it may be done in an infinite number of ways, no one of which has any absolute primacy over the others; and each observer chooses the way which best suits the circumstances of his own motion. If we wish to describe natural phenomena in a way independent of the bias of the particular observer, we must have recourse to the language of four-

dimensional analysis. We begin with a "substantial point," which represents the location of a definite particle, together with the instant at which the particle occupied this location, so that four scalar quantities are required to specify a substantial point We then proceed to define various four-dimensional vectors, the "absolute velocity," "absolute acceleration," and "absolute force," and formulate the law of motion in the form

mass × absolute acceleration = absolute force.

This law may be expressed analytically in terms of the ordinary coordinates (x, y, z) of the particle m, in the form

$$m\frac{d^2x}{dt^2}\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}} = \mathrm{X}, \text{ and two similar equations,}$$

where v denotes the velocity of the particle and (X, Y, Z) the force acting on it, in the ordinary sense of the term. These equations differ from those given by Newton's laws owing to the presence of the factor $(1-v^2/c^2)^{-\frac{1}{2}}$, and it thus appears that Newton's laws must henceforth be regarded as only approximately true.* E. T. W.

Cosmogony.

The appearance of the second volume of Sir George Darwin's collected works, including his papers on "Tidal Friction and Cosmogony," has coincided with the publication of a severely critical account of those same papers at the hands of the authors of the rival "Planetesimal Hypothesis" ("The Tidal and other Problems," Carnegie Institution of Washington, 1909. For references to other papers see page 8). This calls for some comment. During the past twelve years Professors T. C. Chamberlin and F. R. Moulton of Chicago University have been engaged in constructing a theory of the evolution of the solar system which should replace Laplace's nebular hypothesis. This latter hypothesis, attacked by Babinet and Kirkwood, has now been very seriously undermined, in anything like its original form, by the criticisms of Chamberlin and Moulton. Difficulties arising from the relative masses and moments of momenta of the different planets have been forcibly pointed out, and it has been made clear that the evolution of the planets by the separation through *rotational* instability of rings of matter from the central condensation must be abandoned. The alternative fission theory—associated mainly with the name of Mr. J. H. Jeans (*Phil. Trans.*, 199, 201A)—that secondary condensation nuclei might be formed by *gravitational* instability in the gaseous nebula, has not yet been faced by Messrs Chamberlin and Moulton; it must, however, be shown to be inapplicable

* *Cf.* M. Planck, *Deutsch. Phys. Gesell. Verh.*, 1906; and H. Minkowski, *Gött. Nach.*, 1908.

to the solar system before the planetesimal hypothesis can win general adhesion. A similar criticism may be levelled against Moulton's most recent discussion in "Tidal and Other Problems." Many of his objections to Sir George Darwin's work on the Earth-Moon system only apply to the hypothesis of fission under *rotational* instability—a hypothesis not defended by Darwin. Both theorists would probably agree that fission, if it took place, must have occurred before condensation from a nebulous condition was anything like complete. Still, even granting the fission, both Chamberlin and Moulton find many difficulties in following Darwin's subsequent account of the action of tidal friction. At its present rate, they contend, the action is too slow to have had any appreciable effect during the most extravagantly long periods of time. This conclusion of theirs is based on a constant condition of the Earth during the past. Darwin's very different time-estimate based on a changing condition brought the required changes quite fairly within possible limits of time. Chamberlin suggests that the effect of the tides in our complex ocean beds might not necessarily slow down the Earth, but subsequent results of Moulton's seem inconsistent with this suggestion. The geological arguments brought forward to contest the hypothesis of former rapid rotation of the Earth are outside the scope of this criticism, but they lose some of their weight if the hypothesis of mere *rotational* instability is abandoned. It should be added that the acute criticism of the tidal theories advanced in the book discussed above calls for reply on several points from those interested in the defence of the older theory.

Very much the same may be said of the attacks of the same critics on the nebular hypothesis in one of the modified forms current in modern writings. Though they have not been uniformly successful, notably, we think, in the repeated reference to Phobos, they attack the older theory very gravely from several points of view. The theory which they offer as an alternative may be very briefly sketched. A spiral nebula is supposed to be formed from a sun by the passage close by of another star; the consequent ejection of matter forms two spiral arms bearing nuclei at irregular intervals. The particles of these arms all move round the central nucleus in elliptic orbits, and gradually become absorbed by one or other of the nuclei. We may note here that the regularity of the orbits of the particles differentiates this theory from the meteoric hypothesis. The planets are formed by the gradual growth of these nuclei through the accretion of the small "planetesimals," and, according to the authors of the theory, all the phenomena on which the ring theory rested are explained by this new hypothesis. Applications of the theory are made, we think with but moderate success, to explain the equatorial acceleration of the Sun, the eccentricity of retrograde orbits, and other phenomena. Of necessity these applications are somewhat vague, and further evidence in favour of the hypothesis seems badly wanted. Spectroscopic evidence from the study of actual spiral nebulæ, of such motions as are indicated by this hypothesis,

would give valuable quantitative support to a theory which rests mainly on a basis of qualitative constructive reasoning and quantitative destructive reasoning.

Other important work in Cosmogony appearing during the last year includes an article on "The Genesis of Double Stars," by Sir George Darwin, published in the Darwin memorial volume at Cambridge. This gives an interesting historical account of the work on revolving liquid bodies which has been done by Poincaré, Jeans, Liapounoff, Roberts and others, together with an application of the results to the Algol variables. Reference could well have been added to a paper of Jeans (*A.P.J.*, 1905, p. 17), in which he showed that the result of regarding the stars as gaseous instead of as composed of incompressible fluid, was to render nugatory the interesting speculations of certain other workers on the densities and masses of binary stars.

Dr. Friedrich Nölke (*Das Problem der Entwickelung unseres Planetensystems*, Berlin, 1908) has considered the effect of a resisting medium in the evolution of the solar system from a primitive nebulous condition. He adopts the hypothesis that molecular rather than gravitational forces were operative in the early stages of the evolution. But his claim to have explained many of the as yet unsolved problems of cosmogony is hardly substantiated by his work. The same may be said of a series of papers in the *Astronomische Nachrichten*, in which Dr. T. J. J. See has also drawn attention to the effect of a resisting medium upon the orbits of planets and satellites. His work on periodic orbits in a resisting medium is suggestive, but the mathematical treatment is not complete enough to carry conviction nor to justify acceptance of his results. F. J. M. S.

Stellar Spectroscopy in 1909.

Nebulæ.—The spectra of various nebulæ have been photographed by Dr. Max Wolf at Heidelberg (*Ast. Nach.* **180**, 151). N.G.C. 6210 yielded ten bright lines with a short exposure. N.G.C. 6960 (HV 15 Cygni), N.G.C. 6992 (HV 14 Cygni), and N.G.C 2023 are all gaseous. In connection with the ring nebula in Lyra, the most striking results are that H_α is as bright as the other hydrogen lines when a panchromatic plate is used, and that the different lines show different extents of diffusion in the ring. Some of these observations are discussed by Eberhard in *Ast. Nach.* **180**, 357.

An interesting investigation of the spectra of some spiral nebulæ and globular clusters has been made by F. E. A. Fath with the Crossley reflector of the Lick Observatory (*L.O.B.* 149). Fourteen absorption-lines were measured in the great nebula of Andromeda, so that this may be a cluster of solar stars as previously suggested by the work of Scheiner and Huggins. It is suggested that the spiral nebulæ may be unresolved star clusters with vary-

ing gaseous envelopes No spiral nebula which has been investigated has a truly continuous spectrum; they vary from those having chiefly bright lines to those containing only absorption-lines of the solar type.

Classification of Stellar Spectra.—Contributions to classification are contained in the following papers: —

Müller and Kempf (*Ast. Nach.* **180**, 249). Relation between magnitudes and colours of 14,172 stars.

Bell (*M.N.*, lxix. 420). Note on Mr Franks' analysis of the colours and magnitudes of 3630 stars.

Franks (*M.N.*, lxx. 47). Stars of spectral Type *O*.

Franks (*M.N.*, lxx 187). Star colours and spectral types.

Cannon (*Ann. H.C.O.*, lvi., No. 4). Classification of 1477 stars by means of their photographic spectra.

Identification of stellar lines and bands.—The chief outstanding lines in the spectrum of ϵ Orionis have been identified by Lockyer, Baxandall, and Butler (*Proc. Roy. Soc.*, vol. 82, p. 532). Two lines at 4097·4 and 4379·8 have been found to be due to nitrogen, lines at these wave-lengths having been observed to be greatly strengthened when nitrogen is submitted to the action of very powerful sparks. The prominent stellar pair at 4647·6, 4650·8 is attributed to carbon.

A further investigation of the band spectra of the Third Type stars, as represented by *o* Ceti, has been made by Fowler (*M.N.*, lxix. 508). It is shown that numerous bands in the red, as well as those in the green and blue previously discussed, are due to oxide of titanium.

Variable radial velocity.—Notes on investigations of the variable radial velocities of the following stars have been published during the year. Orbits are given for those marked with an asterisk.

ν Aquarii	Plaskett, Ottawa Obs.	*Jour. R.A.S.*, Canada, vol. ii. No. 5
Andromedæ	,, ,,	,, ,, ,,
β Orionis	,, ,,	*Ap. J.*, xxx. 26
Orionis	Frost, Yerkes Obs.	,, xxix. 235
Persei	,, ,,	,, ,, 236
30 Tauri	,, ,,	,, ,, 237
B.D. + 15°637	,, ,,	,, ,, 237
42 Tauri	,, ,,	,, ,, 238
69 Tauri	,, ,,	,, ,, 239
54 Tauri	Lee, ,,	,, ,, 240
97 *i* Tauri	,, ,,	,, ,, 241
71 Tauri	,, ,,	,, ,, 241
92 σ^2 Tauri	,, ,,	,, ,, 242
58 Cassiopeiæ	Frost and Lee, Yerkes Obs.	,, xxx. 62
37 ϕ^1 Orionis	,, ,, ,,	,, ,,
42 *c* Orionis	,, ,, ,,	,, ,,
39 Tauri	,, ,, ,,	,, ,,
Scorpii	,, ,, ,,	,, ,,
72 Ophiuchi	,, ,, ,,	,, ,,
43 ϕ Draconis	,, ,, ,,	,, ,,
59 *d* Serpentis	,, ,, ,,	,, ,,

β Equulei	S. A. Mitchell, Yerkes Obs.	*Ap. J.*, xxx. 239
δ Trianguli	,, ,,	,, ,,
γ Lyræ	,, ,,	,, ,,
θ Virginis	,, ,,	,, ,,
o 78 Virginis	,, ,,	,, ,,
24 o^2 Canis Majoris	,, ,,	,, ,,
ζ Canis Majoris	,, ,,	,, ,,
*ι Orionis	Plaskett and Harper, Ottawa Obs.	,, xxx. 373
*B.D. −1°1004	,, ,, ,,	,, ,,
*α Virginis	Baker, Allegheny Obs.	*Allegheny Pub.*, vol. i., No. 10
*u 68 Herculis	,, ,,	,, ,, No. 11
*2 Lacertæ	,, ,,	,, ,, No. 13
*α Coronæ Borealis	Jordan, ,,	,, ,, No. 12
*π^4 Orionis	Baker, ,,	,, ,, No. 15
Piazzi, 234	Jordan, ,,	,, ,, No. 16
51 Tauri	,, ,,	,, ,, ,,
i Tauri	,, ,,	,, ,, ,,
Bradley, 716	,, ,,	,, ,, ,,
*ζ^1 Lyræ	,, ,,	,, ,, No. 17
30 H Ursæ Maj.	Schlesinger, ,,	,, ,, No. 19
B.D. +3°2867	Baker, ,,	,, ,, ,,
B.D. +6°2875	Jordan, ,,	,, ,, ,,
25 Serpentis	,, ,,	,, ,, ,,
ι Coronæ	Baker, ,,	,, ,, ,,
*δ Libræ	Schlesinger, ,,	,, ,, No. 20
β Ursæ Maj.	Ludendorff, Potsdam Obs.	*Ast. Nach*, **180**, 265
ϵ ,, ,,	,, ,,	,, ,,
ζ ,, ,,	,, ,,	,, ,,
β Orionis	,, ,,	,, **183**, 1
β Aurigæ	,, ,,	,, **183**, 113
*Y Sagittarii	Duncan, Lick Obs.	*L.O.B.*, 151
*RT Aurigæ	,, ,,	,, 151, 160
*X Sagittarii	Moore, ,,	,, 157
A G.C. 8017	Curtis, Santiago	,, 164
A.G.C. 9276	,, ,,	,, ,,
ϵ Volantis	,, ,,	,, ,,
H Velorum	,, ,,	,, ,,
β Cratcris	,, ,,	,, ,,
A.G.C. 15,975	,, ,,	,, ,,
θ^2 Crucis	,, ,,	,, ,,
A.G.C. 19,597	,, ,,	,, ,,
e Lupi	,, ,,	,, ,,
ζ Triang. Aust.	,, ,,	,, ,,
δ^1 Telescopii	,, ,,	,, ,,
δ^2 ,,	,, ,,	,, ,,
ι Piscis Aust.	,, ,,	,, ,,

Mr. Plaskett concludes that β Orionis is probably a binary with a period of about 21·9 days. The range of velocity is from +26·09 km. to +18·55 km., and the eccentricity 0·296. Possibly a third body may account for some of the irregularities which have previously led to doubts as to the star being a binary.

The stars 64 Tauri, 97i Tauri, 71 Tauri, and 92σ^2 Tauri belong to the Taurus stream; in each of the last three, lines belonging to both components were visible on the spectrum plates.

In the case of 37ϕ^1 Orionis the radial velocity inferred from the H and K lines of calcium differs decidedly from that derived from other lines, showing a range of 34 km. with an average of +20 km., while the lines of H, He, etc. range through only 12 km., with an

average of +40 km. The system possibly consists of a pair of spectrosopic binaries.

The spectra of both components are found by Frost in 72 Ophiuchi, and doubling of some of the lines is also recorded by Mitchell in β Equulei and β Trianguli.

The orbit of ι Orionis has been re-computed by Plaskett and Harper, and attention is drawn to the remarkable similarity with the orbit of B.D. − 1°1004. The stars are within 5° of each other, and both are helium stars. The periods are nearly a month, and the eccentricities, which are respectively 0·74 and 0·76, are exceptionally high for spectrosopic binaries. In each case the range of velocities is considerably higher than the average, and the velocities of the two systems are nearly identical. The major axes are nearly parallel to the line of sight. Still more remarkable is the similarity in the secondary disturbances, which are almost identical in period, amplitude, and phase.

The spectra of both components in each of the systems α Virginis, u Herculis, and 2 Lacertæ have been investigated by Baker, and definitive orbits for the two components are computed in each case. u Herculis is a variable of the β Lyræ type and has a period of 2·05102 days. The period of 2 Lacertæ is given as 2·6164 days.

Piazzi 234, 51 Tauri, i Tauri, and Bradley 716 appear in Boss's list of stars belonging to the Taurus stream; Mr. Jordan finds that i Tauri has a variable radial velocity; 51 Tauri may perhaps prove to be variable, and if not, it cannot belong to the cluster; while Piazzi 234 and Bradley 716 give results which confirm them as members of the cluster.

The period of ζ^1 Lyræ is 4·29991 days, and the observations are best satisfied by a circular orbit.

δ Libræ is an Algol variable, and Professor Schlesinger's discussion of the radial velocities in relation to the light curve is of great interest. The hypothesis of a dark, or very faint, satellite is found to fit the facts best, and on this supposition the following data, among others, are derived. The bright star has a diameter of 4,500,000 km., the dark one of 4,000,000 km., and the combined masses are $1\frac{1}{2}$ times that of the Sun; if of equal densities, then each star is only 0·026 as dense as the Sun, and the two masses are 0·87 and 0·63; the bright star revolves around the centre of mass in a nearly circular orbit at a mean distance of 2,500,000 km., while the dark star describes a similar orbit at a mean distance of 3,400,000 km.; the orbits are inclined 81°·5 to the line of sight; the distance between the surfaces of the stars is remarkably small compared with their diameters, varying from 1,300,000 km. at periastron to 2,000,000 km. at apastron. It is probable that the rotation periods are the same as the time of revolution, and the broadened lines of the spectrum would thus be accounted for.

The two stars whose orbits have been investigated by Mr. Duncan are variables of the δ Cephei class. All the stars of this

type have been found to be binaries, with periods of revolution equal to those of the light changes, and the maximum light synchronises closely with the maximum velocity of approach, and minimum light with maximum velocity of recession. The various hypotheses which have been put forward are discussed, only to be rejected; and an explanation based upon a variation in the effective thickness of absorbing stellar atmosphere turned towards the Earth is suggested. X Sagittarii is also a variable of the δ Cephei class.

Stars with great radial velocity.—Mr. Curtis (*L.O.B.* 162) gives particulars of three stars with exceptionally high radial velocities, namely:—

Cordoba Zones 5^h 243, +242 km/sec; velocity in space 261 km/sec, which is exceeded only by the 278 km/sec of 1830 Groombridge.

Lacaille 2957; +100 km/sec; velocity in space 150 km/sec.

Lacaille 8362; −132 km/sec.

The Spectrum of Mars.—A quantitative examination of Slipher's photographs of the spectrum of Mars and the Moon has been made by Mr. Very (*Lowell Obs. Bull.* No. 36). The *a* band of water vapour was found to be $4\frac{1}{2}$ times as strong in Mars as in the Moon at the same altitude. A subsequent investigation showed that the oxygen band B was 15 per cent. more intense in the spectrum of Mars than in that of the Moon (*Low. Obs. Bull.* No. 41).

The question of water vapour in the Martian atmosphere has also been investigated by a party from the Lick Observatory at a station on the summit of Mt. Whitney, 14,500 feet above sea-level (*Lick Obs Bull.* 169). It is concluded that the quantity of any water vapour existing in the equatorial atmosphere of Mars at the time these observations were made was too slight to be detected by present spectrographic methods. Professor Campbell discusses the work of Slipher and Very, and gives a most useful account of all previous observations bearing upon this subject.

Determinations of Stellar Temperatures.—Papers dealing with the temperatures of stars, as determined by photometric comparisons of different parts of the spectrum, have been published by Nordmann of the Paris Observatory (*C.R.*, cxlix. 557, 1038). The revised values for the Sun and 14 stars are as follows:—

ρ Persei	2870°.	Polaris	8200°.
ξ Cephei	4260.	α Lyræ	12,200.
δ Cephei (min.)	4550.	β Persei	13,300.
Sun	5320.	γ Lyræ	14,500.
γ Cygni	5620.	ε Persei	15,200.
δ Cephei (max.)	6900.	δ Persei	18,500.
γ Tauri	7250.	λ Tauri	>40,000.
RX Herculis	7350.		

Professors Scheiner and Wilsing have also published the results of their spectrophotometric determinations of the temperatures of 109 stars (*Ast. Nach.* **183,** 97, and *Potsdam Publ.* No. 56).

Their values range from 2800° for χ Serpentis to 12,800° for λ Orionis. The mean results for stars of different classes, according to Vogel's system of classification, are shown in the appended table.

Type.	No. of Stars.	Temperature.
		°
Ia 1	4	9600
Ia 2	22	8700
Ia 3–IIa	16	6300
Ib	8	9500
IIa	7	5400
IIa–IIIa	41	4000
IIIa	7	3200

It is interesting to note that in both series of determinations the sequence of temperatures accords closely with that generally accepted from the sequence of spectral lines.

Miscellaneous.—The existence of a region in Sagittarius, on the southern border of the Milky Way, containing an unusual number of red stars, is announced by Mrs Fleming (*H.C.O. Circ.* 149, and *Ast. Nach.* **181**, 21). There are 21 stars of the third type, six of the third type with bright hydrogen lines, and one of the sixth type.

A well-designed single-prism spectrograph, intended for radial velocity determinations, is described by Mr. Plaskett (*Jour. R.A.S. Canada*, vol. iii. No. 4). It embodies arrangements to provide for constancy of temperature, rigidity, and optical perfection.

A. F.

Star Catalogues.

Poulkovo Catalogue of 6943 *Stars for Epoch* 1885·0.—In the years 1881–1894 Dr. Hermann Romberg, assistant in charge of the meridian-circle of the Poulkovo Observatory, made 33,000 observations with that instrument, and on his retirement from office at the end of 1894 (Dr. Romberg died in 1898) his partially reduced observations were handed over to M. J. Seyboth of Poulkovo for completion, and were published under the direction of Dr. Backlund as volumes v. and vi. of the *Annals* of the observatory. But this was merely a reduction and publication of daily results using the stars of the Auwers' Fundamental Catalogue prepared for the Astronomische Gesellschaft zones, as primary for the reduction of right ascension, and the principal stars of Nyren's Catalogue for the formation of declination, the stars chosen as primary in each case being only those which culminated south of the zenith of Poulkovo, so that the reduction could not be considered final. The further reduction has now been completed by M. Seyboth, and this catalogue, forming vol. vii. part ii. of the Poulkovo *Annals*, for which a place was left in the series, has been published.

The catalogue contains, as is said in the title, 6943 stars, which are of all declinations from 18° S. to the North Pole, some being as faint as magnitude 9. It gives their right ascension, depending on Auwers' Fundamental Catalogue, to two decimal places, and their declination, depending on the system of the Poulkovo vertical circle, to tenths of a second, both reduced to the equinox

of 1885·0, though in some cases the epoch of observation is as late as the end of 1893. Precession of 1885·0 and secular variation, computed with Struve's constants, are given, and proper motion in such cases as it has been determined, the authority for this being always indicated. The reference number in Bradley's Catalogue is given for the stars which appeared in that catalogue.

The Greenwich Second Nine-Year Catalogue (1900·0).—The Greenwich Catalogue immediately previous to this was published in 1900, and was derived from observations made with the transit-circle in the ten years ending with 1896. During the next nine years the observations with the same instrument were made with the object of supplying accurate places of the reference stars which were chosen for the reduction of the plates of the Greenwich Zone of the Astrographic Catalogue. Some other stars were also observed, the clock stars, the stars of the *Nautical Almanac*, and of other ephemerides and some stars whose places were required for miscellaneous purposes. The volume, therefore, is divided into two parts; the first being a catalogue of the stars, 1541 in number, of the classes just enumerated, in the usual form of the Greenwich catalogues; part ii. being a catalogue of 10,127 stars, chiefly the stars in the *Bonn Durchmusterung* down to magnitude 9·0, with a few fainter stars arranged in zones of declination for epoch 1900, one degree wide, from 63° N. Dec. to the North Pole.

The essential points of the right ascensions of this catalogue differ from those of others of the series in at least one particular. The practice of determining the position of the Pole by observations of a close circumpolar star, at successive upper and lower transits, has been given up, and azimuth error is considered absolute when it depends on three determinations above and three below Pole from different stars on the same evening. Since the necessity for the earlier method arose because the places of the circumpolar stars were possibly not sufficiently well known and its efficacy depended on the stability of the instrument for 12 hours, the adoption of the new procedure may be considered advisable, since it is known that the instrument undergoes diurnal changes of position of an order comparable with those of a possible error of the star's place.

The right ascensions of the clock stars depend on observations made in groups which extend at least over 6 hours. The places of the clock stars thus determined have been compared with their places as determined in groups extending over 12 hours, as has been done in former catalogues of the Greenwich series, and the tabulation of the differences derived from this comparison shows them to be scarcely less than those of the catalogue of 1890, so it appears that the limit of accuracy has been reached, and any error that remains must be considered accidental.

A further difference between this catalogue and that of 1890 is that a correction of $+^{s}\cdot054$ has been applied to the right ascensions of all stars as an equinox correction. In the 1890 catalogue it was shown that the observations of the Sun indicated a correction of $+0^{s}\cdot047$, but this was not applied because it was felt that for

certain reasons this correction is somewhat arbitrary. The observations of the Sun in the period covered by the present nine-year catalogue indicate a correction of similar amount, but the actual correction applied is that found by comparison of the Greenwich clock stars with their places in Newcomb's Fundamental Catalogue. The justification for taking the correction from an independent source rather than from the observations of the Sun is found in a paragraph in the introduction to the catalogue, which describes a new method adopted for illumination of the field of view, and gives the result of some experiments. It seems that the absolute time of transit of a star is $+0^{s}\cdot019$ later when observed in the field of view lighted by a reflector outside the object-glass than when it is observed in the field lighted by the older form of illumination, by means of an annulus in the cube. It is evident that the use of artificial light apparently shifts the spider-lines; and since the Sun is observed without and the clock stars generally with artificial light, there is here all the possibility for an additional source of systematic error.

The crucial points in the formation of the North Polar distances of a catalogue such as this are the method of determining the zenith point and the value of the co-latitude adopted. As must be well known, the zenith point at Greenwich is determined chiefly by observing the altitude of stars by reflection from the surface of mercury, and the altitude by direct observation at the same meridian passage, which has given rise to a well-known empirical correction called the R – D. The value of the variable or flexure term of the formula for this correction has been found from the observations on which this catalogue depends to differ in the mean by $0''\cdot3$ from the value of the same quantity in the former catalogue. The later determined value, the use of which would have led to a correction of $-0''\cdot15$ to the adopted value of the co-latitude, has not been adopted, but the value $+0''\cdot600$ sin Z.D. has been applied as the value of the flexure term to all direct observations, which agrees sensibly with that used in the 1880 and 1890 catalogues. The mean value of the co-latitude adopted is that which has been in use for the last thirty years, Professor Albrecht's corrections for variation of latitude being applied to all observations. The procedure adopted ensures the continuity of the series of Greenwich catalogues, and the criterion of its expediency will be found in a large and laborious amount of comparison of the observations of the catalogue *inter se* and with those of other catalogues. Since the major part of the catalogue consists of stars within 26° of the North Pole, observed at upper and lower culmination, there is much material for comparison of results obtained above and below Pole, which has been made and given in full detail. Comparisons have been made with the Greenwich Catalogue 1890, the Cape Catalogue 1900, Carrington's Circumpolar Catalogue for 1855, the Fundamental Catalogues of Professors Auwers, Boss, and Newcomb, and with the Zone Catalogues of the Astronomische Gesellschaft for epoch 1875, issued from the observatories of Kasan, Dorpat,

Christiania and Helsingfors. The comparison of part iii. with the Astronomische Gesellschaft and Carrington's Catalogues, which between them cover the Greenwich Astrographic Zone, has yielded a list of 170 stars having proper motions of more than 20″ per century, which are specially given in the introduction. The details of the determinations of these and of many smaller proper motions, which have been verified by comparison with other catalogues, and required much labour and jndgment on the part of the compiler of this catalogue, are given at the end of the volume.

H. P. H.

The Astrographic Chart and Catalogue.

Volume vi. of the Oxford Zone, containing the measures of rectangular co-ordinates and diameters of 71,035 images on plates with centres in declination +26°, has been issued from the University Observatory during the year, leaving the publication of volumes v. and vii. to complete the zone of plates whose centres lie between declination +25° and +31° inclusive. The other publications of the year are a fascicule from the Algiers Observatory (dated 1908) and two small parts from Catania, one containing the measures of co-ordinates of stars on 15 plates reduced accurately to right ascension and declination, the other being supplementary to the first fascicule from this observatory which was published in 1907, and contains the positions, similarly reduced, of faint stars which were omitted in the 15 plates of the part to which it is supplementary.

At the fifth meeting of the Permanent Committee which was held at Paris in April, reports were presented by the co-operating observatories, from which the following summary of the progress of the work has been partly made, which may be compared with the similar table relating to the Conference of 1900, mentioned in the Council Report for February 1901.

	Declination of Plate Centres.	Number of Plates in Zone.	Catalogue Plates.			Chart Plates published.
			Measured.	Reduced.	Published.	
Greenwich	90–65 N.	1149	1149	1149	1149	1149
Rome	64–55	1040	...	...	54	32
Catania	54–47	1008	90	...	30	...
Helsingfors	46–40	1008	679	679	252	...
Potsdam	39–32	1232	300	280	207	...
Uccle			...	...	...	32
Oxford	31–25	1180	1180	1180	820	...
Paris	24–18	1260	...	540	360	359
Bordeaux	17–11	1260	819	540	360	119
Toulouse	10– 5 N.	1080	698	...	186	177
Algiers	4 N.–2 S.	1260	517	425	280	333
San Fernando	3– 9	1260	1125	323	..	225
Tacubaya	10–16	1260	1121	360	...	108
Cordoba	24–31	1360	299	...	...	...
Perth	32–40	1376	188	188	...	...
Cape of Good Hope	41–51	1512	1402	803	...	...
Sydney	52–64	1400	705	..	...	...
Melbourne	65–90 S.	1149	1149	...	...	...

The figures in columns 4 and 5 have been taken generally from the reports to the Conference, and refer to a date at the beginning of the year. In some cases no figure is given because the available information could not be easily tabulated. The figures in the two last columns refer to 1909 December 31.

With the exception of Rome, Catania, Bordeaux, Toulouse, and Cordoba, which have not yet completed their respective zones, all the Catalogue plates have been taken by the observatories to which they were allotted. At Algiers, where an unfortunate instrumental defect has been discovered, it has been found necessary to re-photograph many of the fields, so that this zone cannot be considered complete.

The publication by Rome, mentioned in the table, was made seven years ago under a former directorate, and there is no mention of further reduction in the report made to the Conference, but this is no doubt proceeding. It seems likely that publication of the Melbourne Zone will not be long delayed. At the Cape of Good Hope a large proportion of the reduction is completed, but comparison of results on corresponding plates, with a discussion of the constants, is to be made before the printing is begun. It will be noticed that the Zone 17° S. to 23° S. is not mentioned in the list. It was resolved at the Conference that this zone, which was originally allotted to Santiago, and afterwards to a proposed observatory at Monte Video, but has not yet been begun, should be divided between the Observatory of Santiago, the new Observatory of Hyderabad, and that of the University of La Plata.

To advance the work of the Zone 24° S. to 31° S. it was resolved that part of the work of the Catalogue of this zone should be undertaken by the Cape Observatory. It may be remembered that some of the plates of the zone allotted to Perth (West Australia) are being measured at the Royal Observatory, Edinburgh. These are not included in the number given in the list, but 32 were reported to the Conference as having been completely measured.

The reproduction of the Greenwich Chart plates was completed at the end of 1909. During the year the distribution of enlarged reproductions has been begun by Rome and the Belgian National Observatory at Uccle, which has undertaken the Zone originally allotted to Potsdam. Almost the whole of the Chart plates of the Helsingfors, Cape, and Melbourne Zones have been taken, and a small proportion have been taken at Catania and Cordoba, but the Chart plates of the zones not mentioned here nor in the list have not been begun. H. P. H.

[*The*

The Astrographic Conference.

In April last, after an interval of nine years, the Permanent Committee once more reassembled at Paris, under the presidency of M. Baillaud, who succeeded M. Loewy as Director of the Paris Observatory, and was thereupon elected President of the Committee. Much had happened in the interval since the preceding meeting. The campaign for the observation of Eros, initiated by M. Loewy in 1900, had been brought within sight of a successful termination: by making special efforts, Mr. A. R. Hinks was able to announce the definitive result for the solar parallax as $8''{\cdot}806 \pm 0''{\cdot}002$ to the opening sitting of the Committee, and to the Académie des Sciences in the afternoon. In spite of the delays necessarily occasioned by this work, many volumes of the Catalogue and leaves of the Chart had been completed and distributed by the observatories, and many questions of importance had presented themselves for settlement. For the first time in the history of the project it was necessary to divide the Committee into separate sections in order to get through the great amount of work to be done. Five sub-committees were appointed as follows:—

A. To review the work done at the various observatories and report progress (President, Turner).

B. To consider a uniform system of photographic magnitudes (President, Kapteyn).

C. To consider systematic errors in the measures, including optical distortion of the objectives (President, Bakhuyzen).

D. To consider questions relating to the selection of reference stars, and the establishment of a uniform system (President, Küstner).

E. To review the Eros work, and make plans for 1931 (President, Backlund).

The *procés-verbaux* of the discussions have not yet come to hand, but a general summary may be given.

A. It became clear that the work is not within sight of completion. The year 1925 was mentioned by many observatories as an estimated date for completion of Catalogue and Chart. Most observatories have done a large amount of measuring plates (with the exceptions of Rome and Santiago); Greenwich and Oxford are complete; Bordeaux, Toulouse, San Fernando, Tacubaya, the Cape, and Melbourne have nearly completed their measures; but reductions and publication are not so well advanced. With regard to the Chart, it appears now probable that it will be ultimately completed: the French are anxious to have it carried through, and are themselves prepared to undertake the whole of the zones including the Ecliptic (which has been a national ambition since the time of Chacornac). But there was apparently no prospect of an early termination of the work.

B. To reduce the various magnitude scales to one system, it was determined to photograph twenty-four representative portions

of the zones at the same altitude as the Pole. The method is essentially that of Professor E. C. Pickering, who has supplied the necessary data for the polar stars. A proposal made by Professor Turner to count the number of images under each heading of the various adopted magnitude scales, and work with these counts, did not find much support. A committee (Backlund, Baillaud, Gill, Hale, Kapteyn, E. C. Pickering, Scheiner, Turner) was appointed to deal with the question of an adopted scale of magnitudes.

C. Some valuable information as to the probable error of the measures was collected and tabulated. Various recommendations were made as to the examination of the instrumental adjustments. The method of Hartmann for testing the objective was recommended; also special plates for optical distortion.

D. There are to be three classes of specially studied stars: fundamental, intermediary, and reference. Fundamental are to be so chosen that there is one in every 25 square degrees, and observed by the co-operation of Greenwich, Leyden, Lick, Kiel, Paris, Pulkowa, Odessa, Washington, Algiers, the Cape, and Sydney Observatories.

Intermediary stars shall preferably be all of the 8th and 9th magnitude, chosen so as to link the reference stars to the fundamental.

The reference stars are of course those selected for reduction of the plates. A committee (Auwers, Boss, Gill, Küstner, Newcomb) was appointed to superintend the selection of fundamentals and intermediaries.

E. The definitive result for solar parallax was announced, as above stated; but it was also shown that the result varied with the magnitude of the reference stars. This slight variation (perhaps due to atmospheric chromatic dispersion) was still to be investigated, as also the lunar equation and a few minor points. As regards 1931, M. Strömgren was charged with making an approximate ephemeris for the opposition, and precise ones for those which precede it.

The scope of the operations will be apparent even from this brief summary. The Committee is altering in character from a body charged with the execution of a single definite piece of work to one which surveys the whole ground of the astronomy of stellar position and magnitude. To these, stellar movements will be added in the near future, if indeed it has not already been added by the following important resolution:—

The Committee would welcome a repetition of the taking of the plates, especially those of the Catalogue, even after ten years only. The measures show such accuracy that even these would furnish some proper motions. The Committee suggest to the observatories that are able to undertake such a repetition that the new plates should be taken at the same hour-angle and on the same day of the year as the originals.

Further details may be found in the *Observatory*, pp. 201 and 242.

The Committee was most hospitably entertained by M. Baillaud and his colleagues. The tragic series of deaths which have smitten French Astronomy in recent years has been extended still further by the loss, since the meeting, of M. Fraissinet, the Secretary of the Observatory, who did so much in organising the details. In recognition of his long and devoted services, especially at the meeting, he was decorated with the Legion d'Honneur. H. H. T.

The Conference of the International Geodetic Association.

On the invitation of His Majesty's Government, the Association held its Triennial Conference in England in 1909. The meetings, under the presidency of General Bassot, took place in the rooms of the Institution of Civil Engineers from September the 21st to the 25th, and afterwards until the 30th at Cambridge.

Sir George Darwin is the official representative of the Government, but on this occasion a number of special delegates from various parts of the empire were in attendance. The Astronomer Royal, the Director General of the Ordnance Survey, Colonel Close of the General Staff, Major Hills, Mr. Glazebrook, and Mr. Hinks represented the mother country; Colonel Burrard, Major Lenox-Conyngham, Captain Crosthwaite, and Mr. Eccles represented the Survey of India; Mr. W. F. King, Government Astronomer, was present on behalf of the Dominion of Canada; Mr. G. H. Knibbs, Statistician of the Commonwealth, came to represent Australia; Sir David Gill, although no longer officially connected with South Africa, was able to tell the Conference about the African Survey, and especially about the triangulation along the thirtieth meridian of east longitude; and Mr. McCaw, who had recently taken part in the geodetic operations near the Uganda-Congo boundary, was present.

Besides these representatives, Captain Lyons, who has retired from his position in Egypt, and Mr. Keeling attended the meetings, and the latter gave an account of the progress of triangulation in Egypt; lastly, Mr. Giblin, who happened to be in London, was invited to attend the Conference, because triangulation in Siam is contemplated.

In consequence of the presence of these numerous delegates, the Conference assumed an altogether exceptional degree of importance as regards the British Empire and those countries in which the officers in charge of the survey are English.

The representatives of the several Powers presented reports on the progress of geodesy in their respective countries during the three preceding years. There were, besides, discussions on several subjects of general interest. Amongst these, the variation of latitude naturally claimed attention, and Dr. Albrecht laid his latest results before the Conference. It was determined to maintain the six special observatories on the 39th parallel of north latitude,

and as far as possible to continue the observations in the southern hemisphere.

No explanation has as yet been found of the so-called z-term, known also by the name of its discoverer, Kimura. The physical meaning of such a term is that the centre of inertia of the Earth oscillates alternately northward and southward with respect to the surface, and it has been suspected that this is a fictitious appearance, due to the inadequacy of the formulæ of reduction of the astronomical observations. But if this were the case the z-terms could hardly fail to emerge with opposite signs from northern and southern observations; yet they are found to agree with a considerable degree of accuracy. Up to the present time, therefore, the physical reality of this extraordinary oscillation seems to be confirmed.

Dr. Helmert gave an account of the progress of the co-ordination of the values of gravity determined by means of the pendulum, and Dr. Börsch spoke of local anomalies in the intensity of gravity and of local deflections of the vertical.

Mr. Hayford explained the laborious investigation of the United States Coast and Geodetic Survey, whereby the deflections of the vertical in the United States have been discussed in such a way as not only to afford an estimate of the depth below the surface of continental areas at which hydrostatic equilibrium is attained, but also to afford revised values of the ellipticity and linear dimensions of the Earth.

Baron Eötvös spoke of his work in Hungary with the torsion balance, whereby small local deviations of the vertical become measurable. The soundness of the results obtained with this remarkable instrument has been confirmed by independent investigations carried out at the Geodetic Institute at Potsdam.

Colonel Bourgeois related the difficulties overcome and the results attained in the French remeasurement of the celebrated arc of Peru; Sir David Gill explained the progress of the Survey along the arc of the thirtieth meridian of east longitude, which will ultimately extend from the southern extremity of Africa to the North Cape, the longest arc of meridian possible on the Earth's surface; Mr. McCaw told the Conference of the $2^\circ\ 20'$ of the same arc recently surveyed in Uganda, towards the expense of which operation the Royal, Royal Geographical, Royal Astronomical Societies and the British Association had made contributions; Dr. Backlund spoke of the arc of Spitzbergen; Mr. King explained the Canadian project for the survey of a great arc of latitude; Mr. Knibbs related the progress of geodesy in Australia; and Colonel Burrard spoke of levelling and pendulum observations through India and into the heart of the Himalaya; he also referred to the possibility of junction with the Russian triangulation in Central Asia.

A valuable discussion took place as to the use of invar wires or tapes in the apparatus of M. Jäderin (who was present) for the measurement of base-lines. There was considerable diversity of

opinion as to the degree of accuracy attainable, as to the advisability of using wires or tapes, and as to the best procedure in the measurement of base-lines. A commission was nominated to collect information on these important points.

A discussion on precise levelling was initiated by M. Lallemand, and a lively debate ensued.

The determination of gravity at sea excited much interest. The Russian Government had generously placed a man-of-war at the disposal of the Association, and Dr. Hecker had just returned from a cruise in the Black Sea. The object of the voyage was to investigate the corrections to be applied to the observations according to the course of the ship. Baron Eötvös had pointed out that centrifugal force is augmented when the ship is sailing from west to east, and diminished on the opposite course. The application of the correction to previous results led to some inexplicable discrepancies, but Dr. Hecker has now been able to clear up the difficulty by showing that adequate allowance had not previously been made for the vibration of the ship.

Another subject, and perhaps the one which claimed the most general interest, was furnished by Dr. Hecker's observations with the horizontal pendulum in a well at Potsdam during a period of nearly seven years. Although the final reductions are not yet completed, he was able in the clearest manner to exhibit the elastic yielding of the Earth's mass by means of diagrams. Some singular anomalies in the observed deflections of the vertical can only be explained by further observations carried out in other sites. It is hoped that the Imperial and Royal Government of Austria-Hungary will, in response to the representations of the Association, grant a subvention in aid of similar observations to be carried out in the deep mines of Przbram in Bohemia. Dr. Backlund also led the Conference to hope that similar work might soon be undertaken in Russia, and possibly the Carnegie Institution of Washington may do the like in America. In any case, England, France, Italy, and Japan cannot offer any suitable sites for this kind of observation.

The Association has been able to assign a small grant to Dr. Hecker in aid of his researches.

This summary of the work of the Conference will have shown that the meeting was one of exceptional interest. G. H. D.

Geo-dynamics and the Figure of the Earth.

The past few years have been fruitful of advances in our knowledge of the conditions governing the stability and shape of a rotating planet, with special reference to the Earth, and it would seem that the present opportunity is a suitable one for presenting a brief summary of results.

We may take as the initial point of our review Professor Jeans'

memoir "On the Vibration and Stability of a Gravitating Planet" (*Phil. Trans.*, A, 201, p. 157). The main question dealt with in this paper is as follows. In an elastic solid, so long as gravitation is neglected, an unstressed configuration of equilibrium is necessarily stable since any displacement from it increases the potential energy. When gravitation is taken into account an entirely different state of affairs is revealed. Such a solid will have a tendency to condensation, either towards a centre or in some more complex manner. If condensation takes place the resulting displacement from equilibrium may either increase or decrease the gravitational potential energy, and if a displacement can be found which effects a decrease sufficient to outweigh the increase in the potential of the elastic forces, the equilibrium configuration will be unstable.

In a previous paper, "On the Stability of a Spherical Nebula," Jeans had shown that for any spherical body displacements can be found such that there is a decrease in the gravitational potential. It follows, therefore, that the spherical configuration of equilibrium may be unstable. Whether it is possible that the Earth is anywhere in the neighbourhood of a critical point of instability becomes important.

Our knowledge of the elastic constants of the Earth is derived from the observed rate of the propagation of earthquake waves. By a comparison of these figures with the figures derived for a "bifurcation point," or point at which the spherical configuration becomes unstable, it is seen that there is an overwhelming probability that the present values of these constants are such that a state of spherical symmetry would be stable. Whether the Earth is now in a state of spherical symmetry is a different question. Looking backward in time through its past history, we must come to a period when the rigidity was so much smaller than its present value that the material would not have had strength to maintain a spherical shape in face of the gravitational instability. There is good reason for considering it possible that the Earth, at the time when it solidified, was in such a condition. Were this indeed the case, it might have solidified in some shape differing from the spherical one. The term "spherical" must be understood as including spheroidal, the rotation being neglected, and no attention being now paid to rotational instability.

Enormous stresses would be set up in such an Earth after consolidation. A configuration which was one of equilibrium for the compressibility which obtained at the moment of solidification would not remain so after the compressibility had been diminished and the rigidity increased by cooling. It would follow that, as cooling took place and as the elastic constants changed, there would be a series of ruptures resulting from the stresses in the interior. By the time the values of these constants had passed the critical point the configuration would have become approximately spherical. Not, however, absolutely so; and it is possible that the Earth, after complete solidification and after a permanent shape

of equilibrium is arrived at, might retain traces of the original unsymmetrical configuration.

To obtain some idea of the type of asymmetry that we are to look for, an examination must be made of the conditions in the immediate neighbourhood of the critical point. Near that point the divergence from the spherical shape is represented by terms proportional to the first harmonic so long as squares of the divergence can be neglected. If taken into account, a term proportional to the second harmonic must be included. The first supposition results in a planet with a surface not quite an equipotential, and a centre of gravity not coincident with the centre of figure. If water were placed on the surface of such a planet it would form a circular sea, while the dry land would form a spherical cap.

It is well known that the Earth may be divided into two hemispheres, one of which consists almost entirely of land and the other of sea. If the pole of one hemisphere be located at the south of England, all the large land masses except Australia and Antarctica will lie in that hemisphere.

If, now, terms proportional to the second harmonic be included, the form becomes pear-shaped, symmetrical about the same axis as before, and not differing materially in the distribution of land and sea, except that the "stalk" of the pear will emerge as land at the antipodes of the assumed pole.

The Australian continent may possibly be this "stalk"; and Jeans thus concluded that an inspection of the shape and grouping of the continental masses showed that the Earth may contain traces of an original pear-shaped configuration, long since deformed by a series of ruptures.

The distribution of the earthquake regions he adduced as supporting this theory. The principal earthquakes tend to lie on a great circle at the equator of the pear. This is the region where, upon the pear contracting to a sphere, the changes in curvature and the relative displacements would be greatest, and where, therefore, earthquakes would be most probable.

In the course of his analysis of the vibrations and instability of a planet stressed only by gravitation, Jeans used an artifice to overcome a difficulty that had confronted other investigators This arises from the fact that the stresses and consequent strains in a body of planetary size are very great, and Hooke's law is no longer valid. The usual treatment of the theory of an elastic solid fails in that it is based upon the assumptions that the body is initially in a state of freedom from stress, and displacements or vibrations about the initial condition are subject to the limitations that Hooke's law is applicable throughout and that the strains are small. To meet this difficulty Jeans introduced forces to counteract the self-gravitation; thereby artificially annulling gravitation in the equilibrium configuration, and obtaining an unstressed body with each element in its normal state. The wide departure from actuality implied in this assumption was pointed out by Lord Rayleigh (*Proc. R.S.*, lxxvii., A, p. 486).

He suggested that the difficulties of a direct treatment of the problem were not so great as had been supposed. The initial state of stress, when the body is assumed in equilibrium, is of the nature of a hydrostatic pressure, and though in the case of a planet it is enormously great, this does not vitiate the ordinary equations, provided that allowance is made for the altered elasticities. A solution of the problem on these lines starts with considering the body as strained by two stress systems, a hydrostatic pressure balancing the gravitation when in equilibrium, and an additional stress, and proceeds on the assumption that, whatever be the magnitude of the hydrostatic pressure, the additional stress can be treated by the usual methods, implying the validity of Hooke's law.

This procedure was adopted by Professor Love (*Phil. Trans.*, A, ccvii. p. 171; see also *M.N.*, lxix. p. 476; *Nature*, 1907 July 4, p. 223), who was of opinion that all available evidence is just as strong in favour of the proposed method as it is in favour of Hooke's law in the sense in which that law is applied in the ordinary theory. The only objection to it is that the material in the equilibrium state is treated as homogeneous and the elasticity as isotropic. The Earth is, however, not homogeneous, and possibly not isotropic, and the densities and moduli of elasticity must be taken at their mean values. The last assumption would not appear to violate facts to any appreciable extent. Observation shows that the velocity of transmission of earthquake tremors through the Earth's interior is independent of the length of the path, and therefore that the elasticity of the interior, apart from the crust, is constant.

Love was able to present a complete solution of the problem. He showed that a homogeneous sphere may be unstable as regards two distortions, the one normal or radial, and the other such that the vibrations can be specified by spherical harmonics of the first degree. In respect of displacements specified by spherical harmonics of any degree higher than the first, every sphere is stable. He was able to calculate the critical values of the constants at the point where each of these two types of instability arises, and he was further able to extend his analysis to include, as regards lateral distortions, the case of a body with a spherically symmetrical distribution of density.

The application of this analysis indicates that a homogeneous solid body of the same size and mass as the Earth, with a modulus of compression as great as that of steel, would have complete gravitational stability. If the modulus were equal to or less than that of glass the planet would be unstable as regards radial disturbances, and a concentration of density towards the centre would take place. If, in this latter case, there were very little rigidity, the planet would be unstable as regards lateral disturbances. If, on the other hand, the mean modulus of compression were decidedly less than that of glass, though not so small as that of mercury, the planet would be unstable as regards lateral disturbances, even though it possessed a considerable mean rigidity.

Collating these results with the known values of the elastic

constants derived from earthquake waves, it is seen that a spherically symmetrical Earth, in its present condition, is completely stable. Thus far Jeans' results are confirmed and strengthened.

Up to this point the rotation of the planet has been neglected, and it has been regarded as at rest under no external forces. The Earth, however, is a rotating body and is under the action of the Moon, an action which at some period in the past history of the two bodies, when they were revolving almost in contact, was much stronger that at the present time.

The Earth, moreover, has a mean density much greater than that of the surface rocks, pointing to a concentration of mass toward the centre, and suggesting that such a concentration may have come about through the elasticity having been once too small for the homogeneous state to be stable. Further, the centre of figure does not coincide with the centre of gravity, suggesting that an instability of the type specified by spherical harmonics of the first degree may have occurred at a previous period in the Earth's history.

As far as can be seen, the only simple dynamical forces which have acted upon the Earth during the past are—(1) the forces giving rise to these two types of gravitational instability; (2) the forces due to the rotation; (3) the tidal forces due to the attraction of the Moon and Sun. Of these, (1) are, as we have seen, represented by a function of the radius and a spherical harmonic of the first degree; (2) are expressed by spherical harmonics of the second and (3) by spherical harmonics of the third degree.

The combination of these three harmonics, provided the appropriate coefficients can be found, should therefore give us a complete account of the actual shape of the lithosphere or rocky nucleus of the Earth at the time of its consolidation, and its situation relative to the geoid or the equipotential surface which coincides with the surface of the ocean.

If the latter be taken at mean sphere level (8400 feet below sea-level), the continents, with the exception of the Antarctic continent, form a continuous block, and there are two great ocean basins, one containing the deep parts of the Atlantic and the Indian Ocean, and the other the deep part of the Pacific. An analysis of the distribution of land and water showed that the actual outlines of these blocks coincided very approximately with one of the contour lines of a spherical harmonic containing terms of the first, second, and third degrees only.

It thus appears that there is evidence to warrant the conclusion that the lithosphere consolidated in the shape of an ellipsoid with three unequal axes, with its centre of gravity displaced from the centre of figure, and with a deformation or "wrinkle" upon its surface expressed by spherical surface harmonics of the third degree.

If, as seems probable, the present shape of the lithosphere is not very different from that in which it solidified, it follows that the outlines of the main continental blocks and oceans have never varied greatly from their present positions.

The problem of determining the magnitude of the tidal deformation produced in the solid Earth by the attractive forces of Sun and Moon was long ago investigated by Lord Kelvin and Sir G. Darwin (Thomson and Tait, *Nat. Phil.*, vol. ii. § 840 *et seq.*).

The former pointed out that by precise observations of the fortnightly and semi-annual tides it might be possible to deduce the amount by which these fell short of the full height calculated on the supposition that the Earth was perfectly rigid. He showed that if the elastic yielding were the same as that of steel these tides would reach heights about two-thirds of the corresponding figures attained on a rigid Earth, and that the change in the attraction of the Earth due to its deformation by the attraction of the Sun or Moon would equal one-half of the tide-generating force of Sun or Moon.

The quantities which enter into the analysis, and in the special case considered by Kelvin give rise to the numbers $\frac{1}{3}$ and $\frac{1}{2}$, are generally called h and k, where (in this special case)

$$\tfrac{1}{3} = \tfrac{2}{5}\, h, \qquad k = \tfrac{1}{2}, \qquad \text{and, in general, } h - k = \tfrac{1}{3}.$$

As the subject was left by Kelvin, the values of h and k depended upon the assumptions that the Earth is homogeneous and incompressible. Professor G. Herglotz (*Zeitschrift f. Math. u. Phys.*, lii. p. 275) showed that, so far as concerned the determination of the quantity k, homogeneity could be dispensed with, and lately Love (*Proc. R.S.*, lxxxii. p. 73; see also *Nature*, 1909 April 29, p. 252) has shown that the hypothesis of incompressibility can also be eliminated, leaving only the assumptions that an equilibrium theory is applicable to the forces in question and that the surfaces of equal density within the Earth are maintained in ellipsoidal shapes by the rotation. Lastly, Sir J. Larmor (*Proc. R.S.*, lxxxii. p. 89; *M.N.*, lxix. p. 480) has proved that even this postulate is unnecessary, and that any law of density which satisfies the ordinary laws of hydrostatics will suffice. The results established are therefore quite generally applicable to any body so constituted as to admit of the application of the equilibrium theory. It is practically certain that the actual constitution is such that a theory of this kind can be applied.

This quantity k, which represents the inequality in the potential of the Earth near its surface produced by the action of Sun and Moon, was found by Love to be expressible in terms of the two nutation periods (306 days in the case of a rigid Earth, and the "Chandler" period of 428 days), the ellipticity and mean radius of the surface, the angular velocity of rotation, and the mean value of gravity at the surface. All these quantities are approximately known, and from them k can be computed and equals $\frac{4}{1\,5}$.

Many attempts have been made to measure directly the tidal deformation of the Earth. Recently Dr. O. Hecker (*Beobachtungen an Horizontalpendeln*, Veröffentl. d. K. Preusz. Geodät. Inst., N.F. No. 32, Berlin, 1907; also *Ueber die Deformation des Erdkörpers*, International Geodetic Association, London, 1909), at

Potsdam, has met with success in this difficult inquiry. By installing a pair of horizontal pendulums in a chamber 25 metres below the ground level, and keeping a continuous record of the disturbance curves, he obtained a result which, when analysed, showed clearly a periodicity in half a lunar day. The curves described by the pendulums show a want of isotropy, and appear to indicate that the Earth has greater rigidity east to west than north to south, which, as suggested by Sir G. Darwin, might be accounted for, at all events partially, by the gyroscopic rigidity due to its rotation.

When the results of tidal observation, both land and oceanic, are combined with the value $k=\frac{4}{15}$ it is seen that $h=\frac{3}{5}$. The amount that the surface of the Earth actually yields to the attractive force of Sun and Moon is therefore $\frac{6}{25}$ of the amount it would yield if the Earth were made of homogeneous incompressible fluid.

This number $\frac{6}{25}$ replaces Kelvin's number $\frac{1}{3}$; and it follows that the Earth is, as a whole, decidedly more rigid than he supposed it to be. **E. H. H.**

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Brussels, Belgian Astronomical Society.
Brussels, Royal Academy of Sciences of Belgium.
Buda-Pesth, Hungarian Academy of Sciences.
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Canada, Royal Society.
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Leipzig, Astronomical Society.
Leipzig, Prince Jablonowski Society.
Leipzig, Royal Society of Sciences of Saxony.
Lisbon, Geographical Society.
Lund, Astronomical Observatory.
Madrid, Astronomical Observatory.
Madrid, Royal Academy of Sciences.
Manila, Philippine Weather Bureau.
Mauritius, Royal Alfred Observatory.
Melbourne Observatory.
Mexico, Antonio Alzate Scientific Society.
Milan, Royal Observatory.
Missouri University.
Moncalieri Observatory.
Montpellier, Academy of Sciences.
Moscow, Imperial Society of Naturalists.
Mount Hamilton, Lick Observatory.
Mount Wilson, Solar Observatory.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Naples Observatory.
Naples, Royal Academy of Sciences.
Natal Observatory.
Neuchâtel Observatory.
New York, Observatory of Columbia University.
Nice Observatory.
Nova Scotian Institute of Science.
Oporto, Polytechnic Academy.
Ottawa, Dominion Astronomical Observatory.
Padua, University Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.

Paris, Bureau of Longitude.
Paris, École Polytechnique.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society.
Pennsylvania University.
Perth Observatory, Western Australia.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Imperial Hydrographic Office.
Potsdam, Astrophysical Observatory.
Potsdam, International Geodetic Central Bureau.
Potsdam, Royal Prussian Geodetic Institute.
Poulkovo, Central Nicolas Observatory.
Prague, Imperial Observatory.
Queensland, Royal Geographical Society.
Rio de Janeiro Observatory.
Rome, Royal Academy *dei Lincei*.
St Petersburg, Central Nicolas Physical Observatory.
St Petersburg, Imperial Academy of Sciences.
San Fernando, Observatory of Marine.
San Francisco, Astronomical Society of the Pacific.
Stockholm Observatory.
Stockholm, Royal Swedish Academy of Sciences.
Strassburg, Royal University Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya National Astronomical Observatory.
Tasmania, Royal Society.
Tokyō, Astronomical Observatory.
Toronto, Canadian Institute.
Toronto, Royal Astronomical Society of Canada.
Toronto University.
Tortosa, Observatory of the Ebro.
Toulouse, Academy of Sciences.
Toulouse, Meteorological Commission.
Toulouse Observatory.
Turin, Italian Astronomical Society.
Turin, Royal Academy of Sciences.
Turin, Royal Observatory.
Uccle, Royal Observatory of Belgium.
United States Coast and Geodetic Survey.
Upsala, Royal Society of Sciences.
Utrecht, Astronomical Observatory.
Vienna, Austrian Geodetic Commission.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Military Geographical Institute.
Vienna, Imperial University Observatory.
Vienna, Von Kuffner Observatory.
Wanganui Astronomical Society.
Washburn Observatory.

Washington, Carnegie Institution.
Washington, Navy Department.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Naval Observatory.
Yerkes Observatory.
Zi-Ka-Wei Astronomical Observatory.
Zürich, Central Meteorological Institute of Switzerland.
Zürich, Geodetic Commission of Switzerland.
Zürich, Natural History Society.
Zürich Observatory.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of the "Astronomische Nachrichten."
Editor of the "Astronomisches Jahresbericht."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
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ADDRESS

Delivered by the President, Sir David Gill, K.C.B., on presenting the Gold Medal of the Society to Professor Friedrich Küstner.

The Gold Medal of the Society has been awarded to Professor Friedrich Küstner, Director of the Royal Observatory, Bonn, for his Catalogue of Stars, his pioneer determination of the Aberration Constant from motions in the line of sight, and his detection of the Variation of Latitude.

Astronomy in one sense or another appeals to minds of widely different orders. To the mathematician it offers problems of infinite interest; but, as we all know, there have been most distinguished workers in the field of astrodynamics to whom the spectacular glories of the heavens do not appeal,—to whom the first sight of an object like Saturn or a great star cluster as viewed through a good telescope brings no thrill, no insatiable desire to see more, or to acquire or devise means for so doing. Such men are too apt to regard the art of observing as a mere mechanical operation that is unworthy of their practical study. But they are thus frequently placed in the position of having to employ observations about which they have not the capacity to distinguish between the good and the bad.

There is a larger number of persons who are not wanting in the emotional response to their first telescopic sight of celestial objects; some of these acquire, or are driven to construct, instruments to indulge their awakened curiosity; and not a few of them afterwards do useful work as astronomical observers.

The attributes of the great majority of astronomers lie between these two extremes. But the number of men who possess the true fire and natural capacity for the most refined original research in the field of astrometry is limited. Such men must have an inborn natural mathematical, mechanical, and manipulative aptitude; the critical faculty to discern the possible sources of error to which any class of observations may be liable, with the inventive capacity to devise means for their elimination; and that persistent patience and divine discontent with their own best efforts which alone can lead to the highest and most refined class of work.

Our Medallist is supremely a man of this latter type.

The greatest teacher of practical astronomy since the days of Bessel was unquestionably Winnecke, and he fully realised the fact that the true practical astronomer is "born, not made."

Before accepting any student for his higher practical course, Winnecke insisted first upon the necessary educational equipment in mathematics and physics, and then a practical test as to

whether the aspirant had the stuff in him to make a good practical astronomer. That test was generally the following problem: "Given a sextant in bad adjustment, to put it into good observing order, and then to determine with high accuracy the excentricity of its graduation by measures of angles between many different fundamental stars situated at many different angles apart."

This meant a matter of laborious observing for six or eight weeks, in addition to a large amount of routine computation. The preparation of the best kind of programme for this purpose also formed a very good test of the aspirant's judgment and capacity.

When, in 1879, I had the privilege of spending a few days with Winnecke at Strassburg, he told me that when a student passed this ordeal successfully he always found it possible to make him a good practical astronomer; on the other hand, this test cooled the ardour of the majority of aspirants, and left him only students of a suitable kind.

Our Medallist, at the age of nineteen, was one of the first to enter that small but brilliant school. His fellow-students were Hartwig, and later Elkin, Ambronn and Hermann Struve—all of whose names are now household words in astronomy.

Winnecke at first (1876) had no observatory at Strassburg. It was only from the garrets and the roof of the old academy that observations with portable instruments could be made. But the instruments used for the German Transit of Venus expeditions of 1874, under small transportable buildings, were set up in the square in front of the academy, affording the students an opportunity to make observations and investigations of every kind; and every student was animated by the example of the industry and enthusiasm of his venerated master.

The following investigations were made under these circumstances by Küstner when a student:—

1. Latitude of Strassburg (*Ast. Nach.*, **89**, p. 149).
2. Observations of Minor Planets with the Ring Micrometer (*Ast. Nach.*, **90**, p. 363).
3. Measurements with various Heliometers of Sun-diameters, Mutual Distances of the Stars of the Pleiades, etc. (Auwers, *Venusdurchgänge*, vol. iv. pp. 152 and 214).
4. Diameter of Mars (Hartwig, *Pub. Astr. Ges.*, No. xv. p. 57).

In the autumn of 1878 the Philosophical Faculty of the Strassburg University, on Winnecke's instigation, offered a prize for a determination of the Moon's diameter by means of observed occultations. The prize was awarded to Küstner, and in May 1879 the paper was accepted by the Faculty as his "Inaugural Dissertation" for the degree of Doctor of Philosophy. The work is published under the title of "Bestimmungen des Monddurchmessers aus 9 Pleiadenbedeckungen" in the *Nova Acta der Leop. Carol. Akademie*, vol. xl. (Halle, 1879).

After completing his studies at Strassburg, our Medallist went in 1879 to the office of the *Berliner Jahrbuch*, where he was occupied with the computation of elements, perturbations, and ephemerides of minor planets. Later on he combined with this work an assistantship at the Royal Observatory, Berlin, where Professor Förster entrusted him with the examination of a new Universal Transit. This instrument is of the form known as a broken transit, but it could be set in any azimuth, and it was also provided with a level for use as a Talcott or equal altitude instrument. (Described in the *Beobachtungsergebnisse der Königl. Sterwarte zu Berlin*, No. 3.)

It appeared to our Medallist that a re-determination of the constant of aberration would afford not only a great test of the new instrument, but might, if successful, be a valuable contribution to astronomy. The time for such a research was peculiarly suitable because of the then recently published researches of Cornu and Michelson on the velocity of light, which, if combined with a reliable value of the aberration constant, would give an independent determination of the solar parallax. The latter constant, apart from its supreme fundamental importance, was then the centre of interest to all astronomers on account of the past transit of Venus of 1874, the opposition of Mars in 1877, and the coming transit of Venus in 1882.

Struve's classic determination of the constant of aberration had been accepted by astronomers ever since 1842; there could therefore be no question as to the desirability of its repetition.

Küstner at first used his instrument, as Struve had done, in the prime vertical, but convinced himself of the superiority of the Talcott method—because of its freedom from the effects of change in the azimuth of the instrument, or of variation in the clock-rate, or of the observer's personal equation. This method, as is well known, consists in the micrometric measurement of small differences of nearly equal and opposite meridian zenith distances, and can be practically freed from all systematic errors except possible effects of unsymmetrical refraction with respect to the zenith.

Our Medallist's further investigations, however, were interrupted in consequence of his selection by Auwers as First Assistant in the German Transit of Venus expedition of 1882 to Punta Arenas. There Küstner distinguished himself by his assiduity and the accuracy of his observations. After his return to Germany (Easter 1883) he became an Assistant at the Hamburg Observatory, where, in addition to his duties in the time-service, he made a series of measures of double stars with the 10-inch refractor (*Ast. Nach.*, **108**, pp. 281).

In the beginning of 1884 Küstner was appointed *Observator* of the Royal Observatory, Berlin, as successor to Dr. Becker in the service of the Pistor and Martin's transit-circle. That instrument was at the time in need of repair, and our Medallist took advantage of the opportunity whilst it was in the makers' hands to return to his work with the universal instrument,—employing the Talcott method

in his observations as the result of his previous experience. A limited programme had to be adopted, because Küstner had to resume regular work with the transit-circle in the autumn of the same year. The results of these observations were published in 1888,* and were at first sight anomalous, because of the impossibly small value of the aberration-constant which their discussion apparently demanded. It was impossible, from the direct and simple form of the observations, to find any instrumental cause for this apparent anomaly—there must be some external cause. It was just possible, although improbable, that there might be a want of symmetry in the refraction with respect to the zenith (or, in other words, a shifting of the zero of refraction), depending on the season of the year, but there seemed to be no existing means to determine if this was the case or not.

Küstner laid the work aside for a time, and then, on attacking it again, found that the morning observations of 1884 would not agree with those of the same stars made at the same morning hours in 1885.

There, in fact, resulted from each of the seven pairs of stars a marked concordant change in the value of $\left(\phi - \frac{\delta_S + \delta_N}{2}\right)$ by a quantity in the mean $= +0''{\cdot}204$ p.e. $\pm 0''{\cdot}025$, and this change obviously could not, under those circumstances, be accounted for by a seasonal change of the zero of refraction with respect to the zenith, nor could it be explained by any possible error in the proper motions of the stars. Thus Küstner was enabled to state positively (*loc. cit.*, p. 47) that the latitude had changed by that amount.

It is quite true that our Medallist was favoured by exceptional circumstances in making this discovery.

First, because between 1884 and 1885 the variation of latitude chanced to be very large, and had the effect of producing a suspiciously small apparent value of the constant of aberration.

Second, because the projected motion of the pole on the meridian of Berlin between the spring of 1884 and that of 1885 in reality amounted to a change $= 0''{\cdot}2$, an amount that could be measured with certainty by the refined means and methods employed by Küstner.

But these facts cannot detract from the credit of his discovery of the change of latitude. Had Küstner not first prepared himself by thorough study of his instrument, had he not seized the opportunity when the repairs to the Transit-Circle were being executed to resume an investigation which he had previously been compelled by circumstances to relinquish, and had he not been possessed of the critical faculty to perceive the full significance of observed facts, this important discovery would not have been made.

* *Beobachtungsergebnisse der Kgl. Sternwarte*, Berlin, part 3, under the title, "Neue Methode zur Bestimmung der Aberrations-Konstante, nebst Untersuchungen über die Veränderlichkeit der Polhöhe."

To Chandler we certainly owe the discussion of past observations and the first discovery of the principal term of 14-months in the period of oscillation of the Earth's axis. To Newcomb we owe the first dynamical explanation of the non-coincidence of the 14 month period with Euler's period of 305 days, which had so often previously been sought for in vain.* But it is to our Medallist that unquestionably belongs the merit of first giving to the world such convincing proof of the variation of latitude that the International Geodetic Association felt itself called upon to establish observatories for special study of the subject. Under the same auspices that work is still continued, to the great benefit of fundamental astronomy.

It is unnecessary to follow the subject further, because an accurate history of the whole is given in the excellent Presidential Address delivered by Dr. Common from this chair when presenting the gold medal of the Society to Mr. Chandler, in the year 1896, for his indefatigable researches on the subject.

The establishment of the international chain of Talcott observatories absolved Küstner from following up his researches on change of latitude, and indeed his official duties as observer with the Meridian Circle at Berlin from 1885 to 1891 rendered such an undertaking impossible for him. But the subject seems to have been ever present in his mind, and in 1890 he reverted to it (*Ast. Nach.*, **125**, p. 273 and **126**, p. 233). In the latter of these articles he develops his "cyclical method for the determination of aberration," which offers the means of obtaining that constant free from the effects of change of latitude,—a method which has since been followed at many observatories, but with results for the Aberration-Constant which by no means agree within the limits indicated by their probable errors.

Küstner, indeed (in the same paper) predicts that such discordances are possible, and even likely, to occur from a diurnal shifting of the zero of refraction, and this error may become quite considerable in an unsuitably placed or badly designed observatory.

Independent researches on the value of the Aberration Constant are indeed much wanted, especially if made in opposite hemispheres, where presumably any systematic displacement of the apparent zenith depending on the seasons would take place in opposite senses. It is to be hoped that the Latitude Observatories under the direction of the International Geodetic Committee may be induced to modify their programme in order to deal more effectively with this determination.

Küstner's work with the Meridian-Circle at Berlin from 1885 to 1891 was devoted to the following objects:—

1. A reobservation of the *Zusatz-Sterne* along with the *Hauptsterne*, undertaken at the request of Auwers.

* To my successor at the Cape, Mr. Hough, and to Professor Woodward of America, we are indebted for most valuable analytical researches on the whole theory of the subject, with results confirmatory of Newcomb's original explanation—viz. the fact that the Earth is not a rigid solid, as was assumed in Euler's theory.

2. A reobservation of all the stars of which the proper motions were discussed by Argelander in the Abo Catalogue and the Bonn Catalogue, vol. vii., and its continuation.
3. The comparison stars for the heliometer observations of Iris, Victoria, and Sappho.
4. Sundry other series observed for various purposes, such as latitude stars, occulted stars, and zones of stars, for the scale-value of heliometers.

The whole of these observations, some 7800 in all, have been completely reduced and prepared for press by Küstner in the form of his "Catalog von 2083 Sternen für 1890·0, beobachtet 1886–91 am grossen Meridiankreise zu Berlin." The manuscript has for a long time been ready for printing, but as yet has not gone through press. It has, however, been used by Boss in the construction of his new General Catalogue, and by Auwers for the "Geschichte des Fixsternhimmels." Many of these results are, however, to be found in various publications.*

With reference to one of these publications, it will be remembered that in connection with the heliometer observations of Iris, Victoria, and Sappho, made in the years 1888 and 1889 for determination of the solar parallax, the places of the comparison stars were observed in the meridian at a great number of different observatories, viz. at 9 observatories for Iris, at 23 for Victoria, and at 15 for Sappho. Of the grand total, 9620 observations in all, obtained at all the observatories, Küstner himself made no fewer than 877 ; but this figure by no means represents the comparative value of his contribution. In Auwers' classical discussion of these observations (*Cape Annals*, vol. vii.) the author gives (*loc. cit.*, pp. 702 and 703), as the rigorous result of an exhaustive discussion, the weight of a comparison-star's place derived from 5 observations made at each of the 23 different co-operating observatories. This rigorously computed weight includes not only the accidental but the outstanding instrumental and personal errors. After all the determinable systematic corrections have been applied, the results are—

	Absolute Weight. R.A.	Dec.	Mean Error R.A.	Dec.
			s	″
For a star observed by Küstner 5 times at Berlin	7·2	2·9	±0·012	±0·06
Mean weight of 5 observations at the other 22 observatories . . .	1·55	0·92	±0·025	±0·10

* In No. 2 of the *Beob. Ergebnisse der Sternwarte zu Berlin*, "Resultate der Beobachtungen von 670 Sternen"; in *Ast. Nach.*, **116**, p. 225, "Oerter der vom Monde während der totalen Finsterniss 1884Okt 4 bedeckten Sterne." *Ast. Nach.*, **142**, p. 113, "Ergebniss 1886–91 am gr. Meridiankreise der Berliner Sternwarte angestellten Beobachtungen der Jahrbuchsterne."

In No. 2 of *Veröffentlichungen der K. Sternwarte zu Bonn*, "Untersuchungen über die Eigenbewegung von 335 Sternen." Other series are published in Auwers' *Venus Durchgänge*, vol. v. p. 351, in the footnotes to Auwers' A.G.C. Berl. A., and in vol. vii. of the *Annals of the Cape Observatory*.

where weight unity corresponds to a *mean error* whose square is $0^{s}\cdot001$ in R.A. and $0''\cdot01$ in Decl. of which the corresponding mean errors are given above.

Thus the accuracy of a single observation by Küstner is equal to that of the mean of 4·6 observations by an average observer in R.A., and equal to the mean of 3 observations by an average observer in Dec. It would be difficult to find a better proof than this of our Medallist's practical capacity and skill.

In the autumn of 1891 Küstner succeeded Schönfeld as Professor of Astronomy and Director of the Royal Observatory at Bonn. He found the instrumental equipment of the observatory to be worn out and obsolete, and the two first years of his directorate were occupied in the reorganisation and re-equipment of the observatory.

Towards the end of 1893 the new 6-inch Repsold Transit-Circle was erected and Küstner proceeded to carry out a project which had long been in his mind. Under the auspices of the Astron. Gesellschaft all the stars of the N. hemisphere to the 9th magnitude had been observed in zones at different observatories and reduced to the common equinox of 1875. But notwithstanding the fact that the clock errors and equator-points had in every zone been derived from simultaneous observations of the stars of Auwers' Fundamental Catalogue, the resulting star places of different zones were neither homogeneous with the fundamental system nor with each other, on account of systematic errors due both to the instrument and the observer. When these zones were planned the existence of personality depending on magnitude had not been recognised, and therefore no attention had been paid to the effect of the star's magnitude on the personal equation of the observer either in R.A. or declination, and still less to the fact that this personal error is not constant, but varies by time, by the observer's state of health, and by the conditions of definition.*

* Since the above address was delivered Professor Küstner has called my attention to the following facts:—

W. Struve, in his *Positiones Mediæ* (pub. 1852), p. 64, calls attention to the possible existence of personal equation depending on magnitude.

Argelander (*Bonner Beobachtungen*, Band vi. p. xii, pub. 1867) suspected the existence of personality depending on magnitude. He returned to the subject in 1869, in consequence of the large difference between the results of observations of the planet *Egeria* made at Bonn and Leiden (*Ast. Nach.*, **74**, 263), and found, by observing variable stars, that he himself observed the faintest stars too early. He at the same time investigated his personal error in Dec. depending on magnitude (*Ast. Nach.*, **75**, 353), and found it to be small or non-existent.

In the programme for the A.G. zones, Argelander inserted the following instruction: "It is very probable that the right ascensions of faint and of bright stars are not uniformly observed by the same observer, and that the difference varies with the observer. That is a matter of great importance, and must be investigated if homogeneity in the observations is to be secured. For the determination of such differences in the observation of transits the variable stars are quite adapted. Therefore those who take part in the work are requested to frequently observe a number of variables in the various phases of their brightness."

Professor Küstner adds in his letter to me: "Despite these instructions

As these zones constitute practically our fundamentum of astronomy for 1875·0, so far at least as the fainter stars are concerned, it was most important to provide means for determining the real systematic errors of these zones, and for reducing them all to a consistent system.

Küstner's plan for this purpose was to select a number of stars uniformly distributed over the sphere, and to determine their places in relation to the fundamental catalogue in such a manner as to exclude the possibility of systematic error. If he could succeed in this, and if the proper motions of the selected stars are sufficiently well known, it would become possible to compare Küstner's definitive positions with the corresponding positions of the stars of the original zones, and thus to determine the systematic errors of each of the original A.G.C. zones.

But the magnitude error of each observer both in R.A. and Decl. is a variable quantity, depending on the time and other conditions above mentioned; therefore the systematic errors of the zones of the A.G.C. become very complicated, as they depend simultaneously on the R.A., the declination, and the magnitude—the magnitude-equation differing from hour to hour of R.A.

For these reasons it is necessary to employ a very large number of stars in order to determine so many variable quantities.

To fulfil all these requirements Küstner prepared for the part of the sky between the equator and Dec. 51° N. a list of 7000 stars selected from the A.G.C. zones, which had also been observed on the meridian during the earlier half of the 19th century, and for which, therefore, material existed for determination of their proper motions. Having regard to the requirements of the Carte du Ciel, 3600 additional stars fainter than 9·0 were selected in order to fill up considerable areas where the A.G.C. is wanting in stars.

The whole of this great list of stars was observed in narrow zones by Küstner himself in the years 1894 to 1899, aided only by an assistant who read the circle-microscopes. Further observations, for purposes of revision, were made by him between 1899 and 1903. The results of the whole work are published in his "Catalogue of 10,663 stars for the Equinox 1900·0" (Bonner Veröffentlichungen No. 10).

Every star was originally observed once in each of the two positions circle W. and circle E. excepting about 40 stars which, by oversight or otherwise, were observed twice in one position of the instrument. The revision zones consisted in reobservation of those of the original zones (3° to 5° in breadth)

the matter was rather neglected until your paper in 1878 appeared in the *Monthly Notices*; from that time, also, begins the investigation of the error with the use of interposed screens."

The probable reason why the method suggested by Argelander was not adopted was that the opportunities for observing variables on the meridian at their epochs of maximum and minimum are too infrequent in any particular zone; and besides, astronomers were not so convinced of the general existence of such personal errors as to justify the suspension of their regular zone-work in order to examine the matter.

where there was suspicion that some sensible systematic error had occurred, affecting the whole or part of the work of a previous night. But besides this, the revision work included the separate reobservation of every star against the original observation of which there was any remark, such as "uncertain" or "somewhat uncertain" or "very faint,"—and also in every case when the difference (W — E) between the two observations exceeded a certain quantity. For the Southern Stars this limit of difference was taken as $0^s{\cdot}12$ in R.A. and $1''{\cdot}8$ in Decl., and for stars N. of 40° as $0^s{\cdot}15$ and $1''{\cdot}5$.

To carry to completion, single-handed, a work of this extent, in the somewhat unfavourable climate of Bonn, is no small test of a man's persistence and enthusiasm. But it was in no ordinary routine manner that the work was done. Our Medallist had set himself a very much more complex problem than ordinary zone-work, viz. to produce a catalogue of stars from the equator to the zenith of his observatory which should be free from systematic error in its connection with the Fundamental Catalogue itself, and he set about the work in a very characteristic and thoroughgoing manner.

The chief difficulty to be faced was the effect of personality, depending upon magnitude. It seemed to Küstner not sufficient to determine his magnitude-equation occasionally, because investigations previously made had shown him that his own magnitude equation varies with the time and other conditions; he resolved therefore to eliminate it as far as possible. Accordingly he fell back upon a plan like that which had already been adopted by heliometer observers, viz. before the observation of any particular star, to interpose a wire-gauze screen in front of the object-glass, of such density as to reduce the apparent brightness of that particular star to $8\frac{1}{2}$ magnitude.

Küstner had indeed already adopted this method in the very accurate meridian observations made by him at Berlin in 1885–86, to determine the places of 39 stars, of which disappearances or reappearances had been observed during the total eclipse of the Moon in 1884, October 4 (*Ast. Nach.*, **116**, p. 225).

So far as I am aware, the existence of a difference of personality depending on magnitude in meridian observations was first brought to the notice of the Society by myself in 1878 (*M.N.*, vol. xxxix. p. 98), and its systematic character, as the result of a comparison of the heliometer triangulation with the meridian observations of the Mars comparison stars in April 1879 (the *Observatory*, vol. ii. p. 396, and *M.N.*, xxxix. p. 434). The first meridian observations with the use of interposed screens were made, so far as I know, in 1879, by several of the observers who had co-operated in observing the Mars comparison stars, for the purpose of determining their magnitude error. But Küstner is the first astronomer who has taken the heroic course of *eliminating* his magnitude error by nearly equalising the magnitude of all the stars observed.

Of course it is practically impossible to provide such a number

of different screens as to secure complete realisation of this ideal, but it is at least possible to provide a sufficiency of screens to enable any star to be equalised within 1 or 1½ magnitudes of the adopted standard magnitude.

For this purpose Messrs. Repsold, at Küstner's request, applied in front of the object-glass of the new Bonn Transit-Circle a light 4-spoked wheel, of which 3 of the quadrants are filled by wire gauze screens of absorbent powers, corresponding approximately to 2, 4 and 6 magnitudes. This wheel is attached to the outer tube of the Transit-Circle, and does not therefore affect the flexure of the instrument. It can be conveniently rotated in front of the object-glass, in a plane normal to the optical axis, and be conveniently set by a handle at the eye-end, so that a star may be viewed at pleasure either with the unobscured object-glass or through any of the 3 screens.

Thus if a star's magnitude is known, and if the absorption of the screen employed is also known, it follows that the star magnitude, as it appears to the observer in transit, will, in a normal state of the sky, be also known. Thus, for example, if a star of known magnitude 3·0 is observed in transit with screen II., whose absorption is, let us say, 4·2 magnitude, the star's apparent magnitude to the observer at its transit will be 7·2. We require then to know what is the correction to be applied on account of the observer's *difference* of personal equation for stars of magnitude 7·2 and 8·5. Or the same third magnitude star may be observed with screen III. (absorption 6·4); it would in that case have the magnitude 9·4, and would require an opposite correction for magnitude from that of the observation previously described. On the other hand, if a star's true magnitude is 9·4, it would necessarily be observed without a screen, and its time of transit would require the same correction as that of the last case quoted.

Thus, for the rigorous reduction of the observations it is requisite to know:—

1. The light absorption of each screen, expressed in magnitudes.
2. The observer's magnitude-error per magnitude over a small range of magnitude.
3. The true magnitude of each star.

Küstner determined the actual absorbing power of each of the screens by observing stars of known magnitude in transit which are nearly equalised in brightness when one star is screened and the other not so—employing as known magnitudes those of the Potsdam Photometric *Durchmusterung*, and estimating the residual differences of magnitude.

Dr. Mönnichmeyer, at Küstner's request, during an interruption of the meridan circle observations, applied the transit-circle screens to a 6-inch equatorial at Bonn which has an object-glass precisely similar in aperture, focal length, and quality of glass with that of the transit-circle, and he employed the same magnification (140 diameters) as that employed by Küstner. He selected a

number of pairs of neighbouring stars from the Potsdam Photometric *Durchmusterung*, such that when one of them is screened by one of the screens, the other star shall not differ from it by more than 0·4 in apparent magnitude, and so also that, in the mean of the various pairs selected, the mean difference of magnitude should be as nearly zero as possible. In this way, by estimating the residual difference of magnitude, the absorption of the screen can be very accurately determined. At Küstner's request, Dr. Guthnick, with the Zöllner photometer belonging to the Bonn Observatory applied to the Merz equatorial at Berlin, determined the absolute absorption of the three screens quite independently. The results are as follows for stars of mean colour :—

	Küstner.	Mönnich-meyer.	Guthnick.	Adopted. First Approx.	Adopted. Final Approx.
Screen I.	2·04 mag.	1·99	2·02	2·01	2·03
,, II.	4·15 ,,	4·20	4·28	4·18	4·22
,, III.	6·33 ,,	6·34	6·45	6·34	6·36

Küstner has determined his magnitude-equation by comparing the R.A. of the same fundamental star when differently screened on different nights. Thus a 4th magnitude fundamental star might be screened down on one night to 8th and on another night to 10th magnitude, or a 5th magnitude star on one night to 7th and on another to 9th magnitude, and so on. As the fundamental stars are very frequently observed, the difference in their right ascensions, when differently screened, gives the correction depending on magnitude. In this way the magnitude personality is determined along with the observations, and not as the result of a special series of observations. Obviously, also, the same methods give the personality in declination depending on magnitude.

But the great advantage of Küstner's plan is, that, for the mean magnitude of his catalogue (viz. $8\frac{1}{2}$ magnitude), he secures the perfect certainty that his results shall be absolutely homogeneous with the stars of the mean magnitude of the Fundamental Catalogue, viz. 4·0. His observations at the same time determine with extraordinary precision the systematic errors of the Fundamental Catalogue so far as they depend upon magnitude — an important determination never before made.

But in order to apply these corrections it is necessary to know the magnitude of each star observed, and this our Medallist has done in a most thorough manner, so that his work is not merely a catalogue of precision of a very high order, but also a very accurate photometric determination of the magnitudes of 10,663 stars.

His process was first of all to obtain a distinct mental impression of the appearance of a star of $8\frac{1}{2}$ magnitude, by observing a number of stars of the Bonn *Durchmusterung*. Similarly, mental impressions of the appearance of stars of $7\frac{1}{2}$ and $9\frac{1}{2}$ magnitudes were obtained.

Armed with this preliminary mental picture, Küstner began

his work, and recorded his estimate of the apparent magnitude of each star as it transits.

As all the stars he observes range between the apparent magnitudes of $7\frac{1}{2}$ and $9\frac{1}{2}$, his eye learned to discriminate between small differences of magnitude much better than if his mental picture of the standard magnitude was disturbed by the effort to estimate the magnitudes of a wider range. If the observer's mental picture magnitudes remains constant, then the true magnitude of each star will be found by subtracting arithmetically the magnitude-absorption of the screen employed from the observer's estimate of the apparent magnitude at transit.

Of course such an assumption could not be made.

But in each zone of stars there are a large number of stars of the Potsdam Photometric *Durchmusterung*, so that for each of these stars there is one determination of magnitude as estimated by the observer, and one taken from the Potsdam determinations. Naturally the latter is the more accurate of the two, and it supplies a correction to the observer's estimate. Every star of the Potsdam list which is observed in any zone supplies a similar correction, and the mean of all these corrections for stars of different orders of magnitudes may be regarded as affording a correction in the magnitude scale of the zone that particular night. But every star has been observed at least on two different nights, and the limits of the zones vary in R.A., so that the stars of a particular zone observed on one night may have also been observed partly on two or more different nights, and this offers a control upon the constancy of the magnitude-scale. From these comparisons a further adjustment of the magnitudes depending upon the time becomes possible.

Also, after the mean estimation of magnitude for each night had been corrected there would result from the mean magnitude a comparison between the (Potsdam + Screen) magnitudes with the Bonn estimates of the same, and hence a control is obtained on the Bonn scale of magnitudes.

All these points, and many others besides, are fully and rigorously discussed by Küstner in the introduction to his Catalogue, pp. 37–79 ; and, as it is impossible within the limits of this address to enter into a full account of the work, it must suffice to summarise what remains. Küstner deals with the difficult problem of the variation of the transparency of the air during the progress of the night's work in particular zones, with the effect of the colour of the star on the amount of absorption of the screens, with the effect of atmospheric definition on the estimated scale of magnitudes, and in fact with every detail which the most consummate foresight, skill, and thoroughness can devise. The simple proof of the successful manner in which the work has been done can be obtained as follows.

There occur in Küstner's Catalogue 1491 stars common to it and to the Potsdam Photometric *Durchmusterung*. The observer, in the course of his work, did not know whether any particular

star belonged to the Potsdam catalogue or not; he certainly knew nothing as to its tabular magnitude in that work, and was therefore entirely unprejudiced in estimating that magnitude.

A comparison of the Bonn and Potsdam results gives, therefore, a very searching criterion of the quality of both catalogues.

The average difference of magnitude is practically constant for all the zones of different declinations, nor is there any sensible mean difference depending on the R.A. shown in any of the zones. In the mean of all the stars the *average* difference of magnitude is $\pm 0^m\cdot127$. If it be assumed that the probable error of a Potsdam magnitude is $\pm 0^m\cdot049$, then it follows that the *probable error of a Bonn magnitude* is $\pm 0^m\cdot095$.

Out of the 1491 stars common to both catalogues, there are only two whose magnitudes differ in the two catalogues by $0^m\cdot5$, and these only by $0^m\cdot51$ and $0^m\cdot57$.

The mean differences are briefly shown in the following table.

Bonn Mag. m m	No. of Stars.	Potsdam – Bonn. m
4·00 to 4·99	96	−0·04
5·00 ,, 5·49	144	−0·07
5·50 ,, 5·99	208	−0·06
6·00 ,, 6·49	245	−0·03
6·50 ,, 6·99	247	+0·04
7·00 ,, 7·49	309	+0·02
7·50 ,, 7·99	200	+0·09
8·00 ,, 8·70	36	+0·15

Even the small differences shown in the above table would not have existed had not the Potsdam observers applied certain small systematic corrections in the general catalogue to the original magnitudes of the previously published separate results; only these latter were accessible to Dr. Küstner at the time when he discussed his observations.

The mean difference depending on colour ranges only from $+0^m\cdot04$ for white stars to $-0^m\cdot05$ for yellow stars, whilst the stars of mean colour exhibit no sensible mean differences of magnitude in the two catalogues. These figures amply justify our recognition of the fact that this work of Küstner's is a supremely valuable photometric catalogue.

With regard to the work as an Astrometric Catalogue. The stars were observed in narrow zones, and the zone stars as well as the fundamental stars were all reduced by screens within $\pm 1\frac{1}{2}$ magnitudes of the mean magnitude of the zone stars, viz. magnitude $8\frac{1}{2}$. The observations were all made by one and the same observer in the shortest possible time, without change of instrument or method of observation, and by aid of the screens a continuous control was kept upon the personal equation both in R.A. and Decl., depending on the small differences of apparent magnitude from 8·5. All the stars were observed in two positions

of the instrument, Circle West and Circle East. In both positions four microscopes were read; and since for every star different divisions come under the microscopes in the two positions of the circle, a check is obtained from the resulting declinations on the outstanding errors of division of the circle.

In the revision series, of which Küstner gives the separate results, he discusses in the most thorough way the systematic errors of the revision zones and of the detached observations in different declinations, so that practically these revision observations can be combined with the original zones without sensible loss of accuracy.

It is quite impossible, within the scope of this address, to enter into details of the effective and laborious steps taken by Küstner to follow up small changes in his personal error.

Nothing that can contribute to the systematic accuracy of the Catalogue has been neglected, and no doubt can be left in the mind of the most critical reader that Küstner's Catalogue reproduces the system of Auwers' Fundamental Catalogue with practically absolute accuracy when the individual places of the Fundamental Catalogue have been corrected for their magnitude errors to the standard of 4th magnitude. With regard to accidental errors, the following table gives the probable error of *a single observation* as rigorously derived from the inter-agreement of the observations of each star.

Decl.	Stars brighter than 9·5.			Stars fainter than 9·5.		
	R.A.	On Great Circle.	Decl.	R.A.	On Great Circle.	Decl.
	s	″	″	s	″	″
0° to + 9°	±0·024	±0·35	±0·32	±0·026	±0·39	±0·34
+ 9° ,, +18°	·023	·33	·32	·027	·39	·33
+18° ,, +27°	·021	·29	·28	·023	·31	·30
+27° ,, +36°	·021	·27	·26	·024	·30	·28
+36° ,, +51°	·024	·26	·26	·027	·29	·27

Since these probable errors are derived from observations in different positions of the instrument, they include such small systematic errors in declination as may be due to outstanding errors of division in the two different circles employed, and also any possible differences that can arise in R.A. from observation in reversed positions of the instrument; although, from the nature of the observations, it is difficult to imagine how the latter could arise.

The 10,663 star places in the Catalogue depend on 25,469 observations in all, that is to say, on an average of 2·4 observations per star. Hence the average probable error of a catalogue place will be found by dividing the above figures by $\sqrt{2\cdot4}$, that is to say, by multiplying them by 0·65.

Thus, practically in both co-ordinates, the average probable error of a star's catalogue place is only ±0″·20. This is an extraordinary achievement for a single astronomer to accomplish

in a work of such magnitude, especially if we remember that he was hampered with many other duties, such as his lectures to students, and his supervision of the second edition of the charts and catalogue of Argelander's *Durchmusterung*.

In November 1899 the twin refractor, mounted by Repsolds, having a visual objective of 360 mm. aperture and 5·44 m. focus, and a photographic object-glass of 300 mm. aperture and 5·13 m. focus, was erected. The visual telescope not only served for guiding the photographic telescope, but it was also fitted with a very excellent filar micrometer. With this instrument Küstner measured 205 double stars that he had detected in the course of his meridian observations; the results are published in the preface to his Catalogue. Each pair of stars, as a rule, is measured on two, some on three nights, and the observations are of the same high order as the rest of his work.

With the photographic telescope he has made a number of photographs of the Moon and star-clusters. Those of the Moon were made with the insertion of a Barlow lens, by which the image is increased from 5 c.m. to 12 c.m. in diameter. I have not seen these photographs, but Dr. Küstner informs me that, when taken under conditions of the best atmospheric definition, only too rare at Bonn, these photographs are not inferior to those made at Lick, and very little inferior to those at Paris. Some of these plates have been utilised by Professor Franz at Breslau in his selenographical investigations.

Of the numerous clusters which Küstner has photographed, only four have been measured up to the present time, viz. Messier 37, 46, 52, and 92. The measures of Messier 46, made by Zurhellen, are published in No. 11 of the Bonn *Veröffentlichungen*, those of Messier 52 in an Inaugural Dissertation by Pingsdorf. From September 1902 till February 1904 Küstner made a series of photographs to determine the parallax of Nova Persei by Kapteyn's well-known method. The series contained in all 8 plates, each plate having four exposures made at each of three different epochs corresponding with the epochs of maximum and minimum parallax as nearly as was possible consistently with the condition that all the exposures should be made at the same hour-angle. These plates have been measured both by Küstner and his assistant Zurhellen, with the following results for the parallax of Nova Persei, referred to 59 stars of the 9th to 11th magnitude which lie within a radius of 40′ from the Nova, viz.—

Küstner	$: \pi =$	$+0''{\cdot}002$ prob. error	$\pm 0''{\cdot}004$
Zurhellen	$: \pi =$	$+0\ {\cdot}005$,,	$\pm 0\ {\cdot}004$

(*Vierteljahrsschrift* 40, p. 101, and a letter of Küstner to Kapteyn, printed in Kapteyn's *Plan of Selected Areas*, p. 75.)

A similar but more extensive series of plates was made by Küstner between January 1903 and February 1904, at Kapteyn's request, for the determination of the Parallax of the Stars of the

Hyades. These plates are measured and discussed by Kapteyn in the *Groningen Publications*, No. 23.

Küstner's original intention was to continue this parallax work, for the results were supremely satisfactory, but he found that, especially in autumn and winter, it was all but impossible to secure the early morning exposures owing to the fog covering the valley of the Rhine, and also because the exposures were apt to be interrupted in consequence of the extreme vibration of the telescope set up by the passage of neighbouring railway trains. He therefore turned his attention to spectroscopic research, because such vibrations do not sensibly interfere with this class of work. He employed a 3-prism spectrograph, constructed by Töpfer, attached to the 300 cm. photographic telescope; his first results are published in the *Astron. Nach.*, **166**, pp. 177, and the continuation of them in the *Astrophys. Journal*, xxvii. p. 301, where the radial velocities of 99 stars of the 2nd and 3rd spectral type are given. The probable error of a radial velocity derived from a single plate was found to be $\pm 0{\cdot}6$ km. per second. But the chief part of this error arose, not from the accidental errors of the measurement of the displacement of the stellar lines relative to the known lines of the spectrum comparison, but to the unknown wave-lengths of the stellar lines, which in many cases are composite lines of unknown mean wave-length.

Convinced by the internal agreement of his separate measures of individual lines that, apart from the uncertainty of the wave-lengths of the stellar lines, a higher accuracy could be reached, Küstner resolved to attempt a determination of the velocity of the Earth's motion in its orbit by the spectroscopic method. For that purpose it is not necessary to determine the *absolute* velocity of the star, but merely the *difference* of its apparent velocity when, on the one hand, the Earth in its motion round the Sun is most rapidly approaching the star, and six months afterwards, when it is most rapidly receding from it. Each separate stellar line measured under these two circumstances evidently gives an independent determination of the *difference* in the Earth's velocity with respect to the star at these seasons. But the computed velocities corresponding to particular changes of wave-length depend upon an assumed value of the velocity of light. If the eccentricity of the Earth's orbit is known, it is clear, therefore, that we can derive from the discussion of a number of such observations the ratio of the velocity of light to the mean velocity of the Earth in its orbit, and hence, therefore, if the velocity of light be assumed known, the dimensions of the Earth's orbit are known, and hence, if the Earth's diameter is known, the solar parallax is known.

If, then, the Astronomical Constant of Aberration can be expressed by the ratio of the Earth's mean velocity in its orbit to that of light, we have also a determination of the Constant of Aberration. Whether this is rigorously the case is a knotty question, which need not be discussed on the present occasion.

Küstner's work in this direction is published in the *Ast.*

Nach., **169**, p. 241. He there discusses his measures of 18 spectrograms of Arcturus, made in June and July 1904, and in the end of the following December and the beginning of January 1905, determining the velocity in each case with reference to the same 16 lines. The exposures were all made as nearly as possible at the same hour-angle, and every precaution seems to have been taken to eliminate error. The resulting value of the Solar Parallax is

$$\pi = 8''{\cdot}844 \pm 0''{\cdot}017,$$

or within $2\frac{1}{2}$ times its probable error of what we now know, within very narrow limits, to be the true value of the solar parallax. Another important result was to show, that, whereas when assumptions were made as to the absolute wave-length of stellar lines, the probable error of the velocity as determined from a single plate was $\pm 0{\cdot}6$ km. per second, that probable error was reduced to $\pm 0{\cdot}2$ km. when purely differential observations were made to the exclusion of the effect of assumed wave-length of the stellar lines. The determination is avowedly of the nature of a pioneer experiment. Küstner, however, points out with much force the advantages of this method, urging its employment on the ground that it is one of the most important duties of astronomers to employ all possible means and methods for the independent determination of all the relations between the fundamental constants of astronomy.

Our Medallist does not claim to be the first to originate the method, and I may perhaps be allowed to interpolate here an experience of my own.

When visiting Potsdam in 1891, Dr. Vogel showed me some of his photographs of stellar spectra under the micrometer-microscope. After making a number of pointings, and finding they agreed *inter se* with extraordinary precision, I exclaimed—"Why, here is a fine method for determining the solar parallax"—for at that time my mind was very largely occupied with that subject. Vogel, after a moment's reflection, exclaimed exultingly —"Why, yes, of course." Subsequently, at the meeting of this Society in June 1891, I gave a short account of my visits to various continental observatories, concluding my remarks as follows (*Observatory*, vol. xiv. p. 214): "I was very much impressed with the apparatus (Vogel's spectroscope), and having made a number of observations and measured a number of photographs of spectra which Dr. Vogel had obtained with it, came to the conclusion, which I believe is not an extravagant one, that the work done by Professor Vogel with this apparatus is incomparably the most accurate yet done; so much so, that with a 25- or 30-inch telescope, well mounted, and a spectrograph similar to this, employing the largest dispersion that can be used, I believe that by observation of the spectra of the brightest stars it will be possible to measure the velocity of the Earth in its orbit so accurately that the solar parallax will be obtained in this way more correctly than by any other method. That is an enormous advance in exact spectro-

scopic work, and I hope that Potsdam will not be long before it has a telescope capable of doing all that I have suggested. I also hope that Potsdam will not be the only place whence we shall see such results."

So far as I remember, there were not a few members of the Society who at the time expressed the view that I was over-sanguine in my anticipations. These anticipations have been to a great extent justified by the brilliant preliminary work of Dr. Halm at the Cape (*Cape Annals*, vol. x. part 3), under the direction of Mr. Hough, although to our Medallist belongs the honour of first publishing results which prove beyond question the possibilities of the method.

Such has been the career of our Medallist.

In presenting to you this statement of his labours, I have not confined myself to the three works which have been selected by the Council as the special grounds for their award. Whilst these doubtless constitute the most important results of our Laureate's career, I have felt it impossible to overlook his other labours, or to disregard the fascinating study of the train of circumstances and of thought which have led to his successive achievements. No true astronomer can follow Küstner's life without realising the sterling character of the man and his work. Splendidly equipped by nature for the pursuit of practical astronomy, drawn to that pursuit by his love of it, trained in the great school of his revered master, Winnecke, and devoting himself heart and soul to his pursuits, with constant thought and steady endeavour, he has contributed in a remarkable degree to laying strong and deep the foundations of that science to which he has devoted his life.

His career has been marked by that practical common-sense and judgment which are so essential to success. We find him always with high ideals; but he has throughout accommodated these ideals to circumstances, utilising the means and opportunities at his disposal, and making the most of them. In this way he has gained the high position which he now holds, and well indeed has he turned its accompanying opportunities to account.

No sooner did he find himself in the Chair of Astronomy at Bonn than he set about the re-equipment of his Observatory; no sooner was he in possession of a new transit-circle than he proceeded to utilise it for the work which forms the chief ground of our Council's award to-day. I venture to say, if his great predecessor Argelander could arise now to pronounce a judgment on Küstner's work, it would be one of unqualified approval and enthusiastic admiration.

We, too, more humbly would concur in that judgment. There is no work in astronomy of precision the plan of which has been better conceived, and which in the present state of astronomy was more required. We need that work extended from the Zenith of Bonn to the North Pole, and from the Equator to the South Pole,

and we need it, at least, duplicated. In other words, we require that catalogue of *Étoiles Intermédiaires* which the recent meeting of the Astrographic Congress at Paris has demanded. Küstner has shown us the perfect way; let us hope that others will be found to follow in his footsteps. Küstner's pioneer determination of the solar parallax from motions in the line of sight—the second ground of our award—is another instance of our Medallist's capacity for adapting means to ends to which I have already alluded, and is most typical of his energy and enterprise.

I have already dealt at some length with the third ground of our award—his detection of the variation of latitude. That story is no less instructive; it illustrates Küstner's continuous outlook for opportunity, his scrupulous thoroughness and accuracy, his capacity to appreciate the significance of observed facts, and the soundness of his judgment.

To his minor labours I have already referred in detail, but, taken together, they cover nearly every department of practical astronomy, and he has touched no department in that wide field of research which he has not adorned.

Professor Küstner,—In presenting to you the Gold Medal of the Royal Astronomical Society,—the highest mark of its appreciation of your services to science which it is in its power to bestow,—allow me to congratulate you on the splendid results of your work, and to express, on behalf of the Society, the hope that you may be long spared with health and strength to pursue your indefatigable labours, and to add yet further lustre to the historic Chair which you now fill. Permit me at the same time to express the sincere personal pleasure and satisfaction which it gives me to be the means of conveying to you this token of the Society's highest esteem.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected : —

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Sir David Gill, K.C.B., LL.D., D.Sc., F.R.S.

Vice-Presidents.

Sir W. H. M. Christie, K.C.B., M.A., D.Sc., F.R.S., Astronomer Royal.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
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H. F. Newall, Esq., M.A., F.R.S., Professor of Astrophysics, Cambridge.

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